

AD-A238 530



||  
A  
R  
M  
S  
T  
R  
O  
N  
G  
  
L  
A  
B  
O  
R  
A  
T  
O  
R  
Y

**DESIGNING AN ADVANCED INSTRUCTIONAL  
DESIGN ADVISOR: PRINCIPLES OF  
INSTRUCTIONAL DESIGN (VOL 2 OF 6)**

**Eileen Kintsch**

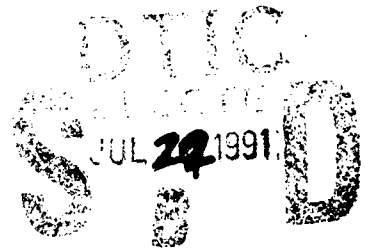
Institute of Cognitive Science  
University of Colorado  
Boulder, CO 80309-0345

**Robert D. Tennyson**

Department of Educational Psychology  
University of Minnesota  
Minneapolis, MN 55455

**Robert M. Gagne  
Daniel J. Muraida**

**HUMAN RESOURCES DIRECTORATE  
TECHNICAL TRAINING RESEARCH DIVISION  
Brooks Air Force Base, TX 78235-5000**



**May 1991**

**Interim Technical Paper for Period August 1989 - March 1991**

Approved for public release; distribution is unlimited.

01 11 092

**AIR FORCE SYSTEMS COMMAND  
BROOKS AIR FORCE BASE, TEXAS 78235-5000**



**91-05100**

## NOTICES

This technical paper is published as received and has not been edited by the technical editing staff of the Armstrong Laboratory.

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely Government-related procurement, the United States Government incurs no responsibility or any obligation whatsoever. The fact that the Government may have formulated or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication, or otherwise in any manner construed, as licensing the holder, or any other person or corporation; or as conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

The Public Affairs Office has reviewed this paper, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

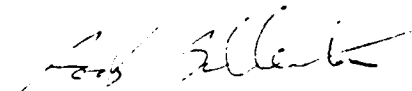
This paper has been reviewed and is approved for publication.



DANIEL J. MURAIDA  
Project Scientist



HENDRICK W. RUCK, Technical Director  
Technical Training Research Division



RODGER D. BALLENTINE, Colonel, USAF  
Chief, Technical Training Research Division

# REPORT DOCUMENTATION PAGE

Form Approved  
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204 Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503

1. AGENCY USE ONLY (Leave blank) 2. REPORT DATE May 1991 3. REPORT TYPE AND DATES COVERED Interim Technical Paper - August 1989 - March 1991

4. TITLE AND SUBTITLE Designing an Advanced Instructional Design Advisor: Principles of Instructional Design (Vol 2 of 6) 5. FUNDING NUMBERS C - F33615-88-C-0003 PE - 62205F PR - 1121 TA - 10 WU - 43

6. AUTHOR(S) Eileen Kintsch Robert M. Gagne Robert D. Tennyson Daniel J. Muraida

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Institute of Cognitive Science Department of Educational Psychology University of Colorado University of Minnesota Boulder, CO 80309-0345 Minneapolis, MN 55455

8. PERFORMING ORGANIZATION REPORT NUMBER 9. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES) Armstrong Laboratory Human Resources Directorate Technical Training Research Division Brooks Air Force Base, TX 78235-5000 10. SPONSORING/MONITORING AGENCY REPORT NUMBER AL-TP-1991-0017

11. SUPPLEMENTARY NOTES These papers were submitted in conjunction with task order #0006 in WU 1121-10-43. They do not constitute the interim or final report.

12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited. 12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words) The Advanced Instructional Design Advisor (AIDA) is an R&D project being conducted by the Armstrong Laboratory Human Resources Directorate and is aimed at producing automated instructional design guidance for developers of computer-based instructional materials. The process of producing effective computer-based instructional materials is complex and time-consuming. Few experts exist to insure the effectiveness of the process. The content of this paper addresses the major implications for instruction based on cognitive and educational research. Principles such as the ones contained in this paper would comprise a substantial part of the knowledge base for the AIDA.

14. SUBJECT TERMS cognitive psychology instructional strategies educational psychology ISD instructional design 15. NUMBER OF PAGES 80 16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified 18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified 19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified 20. LIMITATION OF ABSTRACT UL

## TABLE OF CONTENTS

	Page
I. INTRODUCTION .....	1
II PRINCIPLES OF INSTRUCTIONAL THEORY .....	3
III PRINCIPLES OF INSTRUCTIONAL THEORY FROM RESEARCH ON HUMAN COGNITION .....	9
IV COGNITIVE SCIENCE UPDATE OF INSTRUCTIONAL SYSTEMS DEVELOPMENT MODELS .....	18
V CONCLUSIONS .....	63
REFERENCES .....	64

## LIST OF FIGURES

Figure	Page
1. Relationships Among Learning Theory, Instructional Theory, and ISD Models .....	18
2. Instructional Systems Design Model Linking Cognitive Learning Theory with Instructional Prescriptions .....	45

## LIST OF TABLES

Table	Page
1. Comparison of Baseline and Updated Instructional Systems Design (ISD) Models .....	23
2. Authoring Activities in the Analysis Phase .....	37
3. Authoring Activities in the Design Phase .....	53
4. Authoring Activities in the Development Phase .....	58
5. Authoring Activities in the Implementation Phase .....	59
6. Authoring Activities in the Maintenance Phase .....	61



For	
<input checked="" type="checkbox"/>	<input type="checkbox"/>
Unannounced Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

## PREFACE

The work reported herein was done for the Advanced Instructional Design Advisor project at the Air Force Human Resources Laboratory (AFHRL/IDC). The substance of this research was done under contract to Mei Associates, Inc., the primary contractor on the Advanced Instructional Design Advisor (Contract No. F33615-88-C-0003).

This work was done as part of the first phase effort on the Advanced Instructional Design Advisor. The initial phase of this project established the conceptual framework and functional specifications for the Advanced Instructional Design Advisor, an automated and intelligent collection of tools to assist subject matter experts who have no special training in instructional technology in the design and development of effective computer-based instructional materials.

Mei Associates' final report for the initial phase was published as AFHRL-TP-90-xx. In addition, Mei Associates received 14 papers from the seven consultants working on this phase of the project. These 14 papers have been grouped into 6 sets and edited by AFHRL/IDC personnel. They are published as Volumes 1 - 6 of Designing an Advanced Instructional Design Advisor:

Volume 1: Cognitive Science Foundations

Volume 2: Principles of Instructional Design

Volume 3: Possibilities for Automation

Volume 4: Incorporating Visual Materials  
and Other Research Issues

Volume 5: Conceptual Frameworks

Volume 6: Transaction Shell Theory

This is Volume 2 in the series. Dr. Daniel J. Muraida wrote sections I and V. Drs. Robert M. Gagne, Elieen Kintsch, and Robert D. Tennyson wrote sections II, III, and IV, respectively.

## SUMMARY

The Advanced Instructional Design Advisor is an R & D project being conducted by the Air Force Human Resources Laboratory in response to an Air Training Command (ATC) Manpower, Personnel, and Training Need calling for improved guidelines for authoring computer-based instruction (CBI) (MPTN 89-14T).

Aggravating the expensive and time-consuming process of CBI development is the lack of Air Force personnel who are well-trained in the areas of instructional technology and educational psychology. More often than not, a subject matter expert with little knowledge of CBI is given the task of designing and developing a computer-based course. Instructional strategies that work in a classroom are often inappropriate in a computer-based setting (e.g., leading questions work may work well in a classroom but are difficult to handle in a computer setting). Likewise, the computer offers the capability to present instruction in ways that are not possible in the classroom (e.g., computer simulations models can be used to enhance CBI).

The Advanced Instructional Design Advisor is a project aimed at providing subject matter experts who have no background in computer-based instructional systems with automated and intelligent assistance in the design and development of CBI. The goal is to reduce CBI development time while insuring that the instructional materials are effective.

## I. INTRODUCTION (Muraida)

The Advanced Instructional Design Advisor is an R & D project aimed at providing automated and intelligent assistance to inexperienced instructional designers who have the task of designing and developing computer-based instruction (CBI). The particular problem being addressed by this line of research is the need for more cost effective methodologies for the design and development of CBI. Current methods for developing CBI are expensive, time-consuming, and often result in ineffective instruction due to the general lack of expertise in computer-based instructional systems (Spector, 1990).

The Advanced Instructional Design Advisor project is divided into four phases:

- Phase 1: Conceptualization & Functional Specifications
- Phase 2: Conceptual Refinement & System Specifications
- Phase 3: Prototype, Field Test, & Refinement
- Phase 4: Technology Demonstration & System Specification

The first two phases have been funded with Task Order Contracts. The third phase is being funded by a Broad Agency Announcement (BAA) contract. The work reported herein concerns the first phase.

The following three sections of this paper concern the contributions of cognitive and educational psychology to instructional design. In essence they attempt to provide reader with a summary of reliable principles for the practice of instructional design as gleaned from the cognitive and educational research literatures.

A common criticism of cognitive and educational psychology is that they provide only implications for instructional practice but seldom any prescriptions that can be used in a specific situation. The sections authored by Gagne, Kintsch, and Tennyson, respectively, temper that criticism by focusing on the instructional tasks which have been significantly addressed by research.

Gagne's section is a distillation of psychologically-based instructional theory which includes his collaborative work with Leslie Briggs as well as the work of seven other major instructional theorists. The purpose of this section of the paper is to present the principles that enjoy wide consensus. He begins this task by noting the major distinguishing dimensions among instructional principles. He then presents the major principles that apply to the instructional process from the formation of

objectives to the evaluation of performance.

The initial part of Kintsch's section examines the nature of the learning process as determined by recent cognitive and instructional research. She then presents general conclusions about the conditions which enhance learning coupled with citations from supporting research. In the following sub-section Kintsch examines the role of metacognition, and social environmental factors in supporting the learning process. Kintsch then explains how higher level thinking is related to the thoroughness with which simpler processes have been learned. In each of the preceeding sections Kintsch includes broad directives for instruction. The final two sub-sections Kintsch address the issue of adapting instruction to the changing needs of the student resulting from error analyses or data indicating increases in skill levels.

Tennyson presents an analysis of the potential contribution of cognitive and educational psychology to a major methodology of instructional practice in the military: Instructional Systems Development (ISD). He first covers the traditional ISD model and its major variations, delineating their role in the instructional process. Following this he points out the dated conceptions of learning processes and instructional systems which the baseline model shares with its variations. Tennyson then identifies research-based prescriptions from the cognitive sciences which should become part of ISD in order to successfully address complex instructional objectives. In the final sub-section Tennyson steps through the entire ISD process, showing how prescriptions from cognitive science would be implemented in the design of instructional sequences.



## II. PRINCIPLES OF INSTRUCTIONAL THEORY (Gagne)

### Introduction

The principles listed and defined in this paper are intended to be those concerning which there is much agreement, and virtually no disagreement, among those writers who have put forward theories (or models) of instruction. The theorists included are represented in the book edited by C.M. Reigeluth, Instructional-Design Theories and Models: An Overview of Their Current Status, Erlbaum Associates, 1983. Reigeluth has done a conscientious job of identifying many resemblances and differences among these theories. Although illuminated by his comments, my task here is a different one: to define and describe those principles of instructional design that stand out, after sifting through all the differences, as items possessing broad consensus and little disagreement.

The theories from which common principles of instructional design are to be drawn are as follows, identified by the name or phrase by which they are commonly known:

- a. Gagne-Briggs Theory -- R.M. Gagne & L.J. Briggs
- b. Behavioral Approach -- G.L. Gropper
- c. Algo-Heuristic Theory -- L.N. Landa
- d. Structural Learning Theory -- J.M. Scandura
- e. Inquiry Teaching -- A. Collins & A.L. Stevens
- f. Component Display Theory -- M.D. Merrill
- g. Elaboration Theory -- C.M. Reigeluth
- h. Motivational Theory -- J.M. Keller

### Some Differences

The task of finding common principles of instruction has to be done against a framework of features that make the theories incoordinate in several respects. Prominent differences are these:

(1) Single vs. multiple learning outcomes. Some of the theories focus exclusively on a single kind of outcome. Some deal with the learning of verbal information (declarative knowledge), or solely with the learning of procedures. Others aim for a number of different kinds of learning objectives.

(2) Micro-strategies vs. macro-strategies. Some theories are oriented to the organization of large units of instruction, such as courses or course segments. These macro-strategies contrast with micro-strategies, focusing on relatively small

units such as lessons and lesson-components, and aimed at single objectives such as a concept or a procedure. Most of these theories deal with micro-strategies.

(3) Discovery learning vs. expository teaching. One of these theories exclusively uses instruction that requires the learner to arrive at the proposition to be learned by "putting together" in a novel fashion items of knowledge already possessed in memory. Most theories allow for the occurrence of such discovery learning at some points during instruction. With greater or lesser degrees of emphasis, they employ questioning techniques designed to facilitate the discovery of what is to be learned.

### Design Principles

According to design theories, these are the principles that will yield optimal learning:

\*1. DIFFERENT LEARNING OBJECTIVES REQUIRE DIFFERENT INSTRUCTIONAL STRATEGIES. Instruction for removing insulation from the end of a wire is different from instruction for knowing the names and functions of the components of an electronic circuit. Instruction on the origins of the American Revolution is different from instruction on analyzing cases in business law. Instruction aimed at reducing the use of harmful drugs is different from instruction on diagnosing illness. (Gagne-Briggs, Merrill, Gropper, Reigeluth).

Importance: 10.

Recognizing different categories of learning objectives is a task that requires some educational background and experience. Novices can usually not learn these procedures rapidly. Requires a good course in instructional design. Training requires a good deal of practice on varied examples, in order to establish the understanding that will assure valid and reliable categorization of specific instances.

\*2. FIVE DIFFERENT TYPES OF LEARNING OBJECTIVES ARE THE FOLLOWING. Particular instructional strategies that are most distinctive for each type of objective are listed.

- a. Verbal knowledge (declarative knowledge). Relate to organized knowledge already known. Use spaced review. (Gagne-Briggs, Merrill, Gropper).
- b. Concepts. Provide definition, examples and non-examples, practice in identifying new examples. (Gagne-Briggs, Merrill, Gropper, Landa).

c. Procedural rules. Assure that component parts of procedure are mastered before total skill is tried. Practice on examples, verify on new examples. (Gagne-Briggs, Merrill, Gropper, Landa, Scandura).

d. Motor skills. Practice with reinforcement. (Gagne-Briggs, Merrill, Gropper).

e. Attitudes. Demonstration by human model. (Gagne-Briggs).

Importance: 10.

Assuming that learning objectives have been properly identified, the task of matching them with appropriate instructional strategies cannot be done by a novice. Requires a good course in "conditions of learning". Training requires practice with a number of different specific performances. The choices of particular conditions of instruction require knowledge of human learning and cognition.

\*3. BEGIN WITH AN EVENT THAT AROUSES AND SUSTAINS LEARNER INTEREST. This may be any attention-getting stimulus. Often, it is an introductory message or demonstration that "grabs" the learner's conscious attention. (Gagne-Briggs, Merrill, Keller, Reigeluth).

Importance: 5.

No particular specialized knowledge is required to put this principle into effect. This is probably acquired readily on the job.

\*4. COMMUNICATE CLEARLY WHAT THE LEARNER MUST LEARN TO DO. This communication may be a statement, a demonstration, or both. It should include an indication of the usefulness of the learned performance to the learner. (Gagne-Briggs, Keller, Collins & Stevens, Reigeluth).

Importance: 7.

This principle is moderately difficult for new designers to learn, and usually takes some supervised practice. It may be noted that the word do is of critical importance. Designers must learn that asking the learner to repeat a verbal statement will not serve the purpose.

\*5. STIMULATE RECOLLECTION OF PREVIOUSLY LEARNED RELEVANT KNOWLEDGE. If the learning objective is procedural, this may be components or prerequisites. If the objective is declarative, previously learned knowledge may be more general, related or

analogous. If the learning objective is motor skill, previously learned knowledge may be part-skills. This principle is an example of the requirement for different learning strategies, in accordance with Principle \*1. (Gagne-Briggs, Gropper, Landa, Scandura, Merrill, Reigeluth).

Importance: 8.

The requirement to identify different kinds of recollection sends us back again to Principle \*2, and the training relevant to that principle. If the designer can do that principle, he should be capable of doing this one.

**\*6. MAKE THE STIMULUS ASPECT OF THE TASK READILY PERCEPTIBLE.**

Avoid uncertainties and ambiguities in what is displayed, visually or auditorially. If the display tends to be obscure or fuzzy, make its main features prominent by enhancement or distortion that is gradually removed. (Gagne-Briggs, Gropper, Landa, Reigeluth).

Importance: 5

Designer needs to learn various techniques of feature enhancement--using bold print, spacing, diagramming, etc.

**\*7. STATEMENT OF RULE, EXAMPLE; OR EXAMPLE, RULE; FOLLOWED BY LEARNER PERFORMANCE. BOTH SHOULD BE PRESENTED, BUT THEIR ORDER IS NOT CRITICAL.** Note that this principle applies only to the learning of concepts and rules, not to verbal knowledge. A general rule (or defined concept) is communicated to the learner, and followed by a concrete instance as a "for example". The learner is asked to respond to the example, thus applying the rule or definition. When discovery learning is employed, the order of presentation of rule:e.g. is reversed to e.g.:rule. (Gagne-Briggs, Merrill, Gropper, Scandura, Collins & Stevens, Reigeluth).

Importance: 6.

This principle is fairly easy to understand, but usually requires some practice for mastery.

**\*8. GUIDE THE LEARNING THROUGH ELABORATIONS.** Mainly, elaboration means extending the meaning of what is presented by relating it to prior knowledge. Sometimes, this is done by means of pictures or diagrams; sometimes, by suggesting analogies; sometimes, by reminding the learner of highly familiar bodies of knowledge. Questioning techniques are particularly good illustrations of learning guidance by the use of elaborations. (Gagne-Briggs, Merrill, Collins & Stevens).

Importance: 7.

The various techniques of elaboration will need to be learned by the designer, as they apply to a variety of specific instances.

\*9. VERIFY INITIAL LEARNING BY LEARNER PERFORMANCE. Arrange one or two "trials" in which learner performance is called for in the absence of prompting or tutelage. Before extensive practice is continued, there should be an occasion on which the learner "shows what he can do". (Gagne-Briggs, Gropper, Scandura, Merrill, Collins & Stevens).

Importance: 7.

The designer usually requires instruction and practice in using techniques that accord with this principle.

\*10. PROVIDE VARIED PRACTICE WITH CORRECTIVE FEEDBACK. Virtually all theories agree that some amount of additional practice should be provided following the initial "trial". To allow for the action of reinforcement, practice trials should include knowledge of results and corrections when appropriate. Varied practice implies the use of examples that are varied in content; also, it means embedding the examples in varied contexts. (Gagne-Briggs, Merrill, Gropper, Scandura, Landa, Reigeluth).

Importance: 8.

This principle is fairly easy to understand, but may require supervised practice in the design of examples and the application of feedback during practice.

\*11. COMMUNICATE THE RELATION BETWEEN WHAT IS BEING LEARNED AND HOW IT WILL BE USED. A part of what is to be learned and stored is a scenario that connects learner performance in the learning situation with projected performance "on the job". As theories usually recognize, such knowledge can be a major factor in the transfer of learning to whatever situation requires the use of what has been learned. (Gagne-Briggs, Gropper, Merrill, Keller, Reigeluth).

Importance: 8.

This principle requires the use of persuasive communications, and the use of knowledge of job performance requirements.

\*12. ARRANGE OCCASIONS THAT REQUIRE RETRIEVAL. Retention of what has been learned demands several additional periods of

practice, spaced over time, and in varied situational contexts.  
(Gagne-Briggs, Gropper, Merrill, Keller, Reigeluth).

Importance: 6.

This principle can readily be understood, but may require periods of supervised practice by the designer in order to assure mastery.

### III. Principles of Instructional Theory from Research on Human Cognition (Kintsch)

#### Introduction

The past two decades of research in cognitive science on human information processing have provided detailed accounts of expert performance in many areas, but as yet no general theory of how expertise is acquired. Despite the lack of a unified learning theory, new tools for the analysis of complex behavior now make it possible to focus our attention on the inexpert learner and on the processes by which new knowledge and new skills are learned. Thus, some agreement regarding instructional principles is beginning to emerge, though there are differences in where the emphasis is placed among several recent programs which attempt to train cognitive processes. To some extent these differences are dictated by the particular aspect of competence that is the focus of instruction. Cognitive research describes three types of knowledge that enter into expert performance: knowledge of the subject domain, usually referred to as declarative knowledge, a set of automatized subprocesses or procedures for operating with the knowledge, and knowledge about the conditions of knowledge use, which acts as an executive control structure. These kinds of knowledge interact in a complex manner in a given task setting and place different demands on the information processing system. Thus, reflecting on and interpreting new knowledge are conscious, resource consuming processes which depend on highly proficient lower-level skills.

A critical review of several instructional programs for cognitive skill development, which are based on current theoretical assumptions about the learning process is provided by Glaser and Bassok (1989). Many of the learning principles summarized below are discussed in depth in that paper. In addition, the reader is referred to a recent volume edited by Resnick (1989) for a general introduction to the theoretical framework and methodological tools used in cognitive research on learning in a number of different domains.

Perhaps the most important influence of cognitive science research on instruction has been to change our concept of the learner, from one whose learning is primarily determined by the form in which the new knowledge is imparted to a person who actively participates in the learning process. It is the process of learning that is now emphasized in both research and educational applications, rather than the transmitting of knowledge (Resnick, 1989). Thus, the learner's attempts to

comprehend, remember, and solve problems are explained in terms of the strategic operations engaged in, and how these function within the constraints of the human information processing mechanism. Most of the principles outlined below derive from this perspective.

### The learning Process

Comprehension in all domains is viewed as an active process of meaning construction by which the learner creates his or her own interpretation of the incoming information. To the degree that the learner is successful at integrating the new information into his or her network of prior knowledge, to the extent that multiple ties and links are forced between pieces of new and existing knowledge, his or her ability to retrieve and use that knowledge is enhanced.

New knowledge is integrated through higher-level inferences, by which relationships are constructed between individual pieces of information, or which serve to elaborate the incoming information with extensions from the store of personal knowledge. According to van Dijk and W. Kintsch (1983; Kintsch, 1989), conceptual understanding derives from generating a memory representation of the situation depicted by a text passage or underlying an abstract problem. Through self questioning and self explanation the active learner strives for conceptual understanding of a problem situation, of an event, or of the principles that relate ideas. Such activities also help the learner to identify specific gaps in his or her knowledge, or discrepancies between prior knowledge and the new information.

Instruction: The goal of instruction, according to constructivist theories, is to engineer conceptual growth. Instruction should therefore be centered on the learner's own knowledge construction activities. That is, it should be designed to encourage and support the learner's independent attempts to interpret, restructure, and use new knowledge, rather than fostering assimilation and reproduction skills. Brown and Palincsar (1989), for example, advocate "learning environments that encourage questioning, evaluating, criticizing, and generally worrying knowledge, taking it as an object of thought" (p. 395).

Learning occurs by extending existing knowledge, however this can happen in several ways:

(a) Knowledge accumulates by adding new facts and ideas to the knowledge base.

(b) New knowledge is also acquired by elaboration and modification of existing knowledge structures. Knowledge is updated by adding, deleting, and generalizing information, and by



creating new relationships between pieces of knowledge that extend the network downwards and outwards to other knowledge structures in memory.

(c) Occasionally, large-scale restructuring of existing knowledge structures becomes necessary. New memory representations are created which encompass a larger body of information or which resolve a conflict between existing and new knowledge. Thus, as knowledge in a subject area expands, a kind of chunking takes place that allows larger, functional units of knowledge to be retrieved from memory and which results in increased processing efficiency. This is referred to as a process of knowledge transformation.

(d) Rapid access to information stored in memory also depends on automatizing routine procedures through practice. Rapid identification of word meanings and syntactic parsing are examples of automatic processes which are essential to higher-level meaning interpretation during reading. Such skills also become relatively independent of specific domain knowledge (Perfetti, 1989).

**Instruction:** In designing instruction, one needs to be aware where students are in the acquisition of new skills, and what kind of knowledge manipulation is important in a given context. In most learning situations different kinds of knowledge building activities interact in a complex fashion, yet in designing instruction one should be clear about where the emphasis is placed. For example, is the goal of a task to foster reflective, interpretive activities or the rapid execution of routinized procedures? For the former cognitive research strongly suggests that more attention should be given to activities which engage the learner in construction and restructuring of knowledge than has been the case in traditional instructional settings, because these kinds of operations form the basis for long-term retention and transfer of new knowledge.

The organization of knowledge in memory determines its accessibility and the depth of understanding that is achieved. Multiple pathways between knowledge structures enables information to be rapidly accessed in memory. Well-connected knowledge also transfers more broadly to other domains.

**Instruction:** Organized knowledge is easier to understand and to remember, but not in the sense of knowledge that is presented in preorganized, decontextualized components to be learned in a bottom-up fashion (Resnick, 1989). Cognitive research has shown that such knowledge is not maintained well over long periods, nor does it transfer as readily to other areas. Instead, instruction should find multiple ways to tie new information to the learner's prior knowledge of a topic. Numerous opportunities should be offered to promote reflective thinking and for recursive

processing of new knowledge. The learner should be encouraged to create multiple representations of the knowledge, for example by means of tasks designed to elicit different organizational schemes, other perspectives, or novel applications.

Transfer of knowledge and skills to other applications also occurs more readily when instruction emphasizes the meaningfulness of the information beyond the specific situation in which it is initially introduced. Compartmentalization of knowledge should be avoided by extending the use of new knowledge, cognitive skills, and strategies across different domains. Instruction should allow the learner to discover common themes or underlying principles that relate different subject areas. "... the observed generality and transfer to learning come from intentional efforts to find links among elements of knowledge, to develop explanations and justifications, and to raise questions" (Resnick, p. 9).

It follows that learning is greatly enhanced when knowledge is learned in a specific context, in the service of a problem that needs to be solved, or to attain a specific cognitive goal. That is, one learns by doing and by understanding the purpose of what one is learning, both in relation to an overall goal and to the particular task at hand

**Instruction:** New knowledge should be taught in a meaningful context, so that its relation to a particular cognitive goal is apparent, not as a sequence of skills learned in isolation. Furthermore, it should be possible for students to mark their own progress through a sequence of subgoals in pursuit of the higher-level learning goal.

Comprehension, writing, problem solving, and learning in general are strategic, rather than rule governed processes. Strategies are an effective means of accomplishing some goal, within given time and resource limitations, but unlike rules, they do not guarantee a correct outcome. Strategies may be more or less optimal, more or less powerful, and they vary as well in terms of the cognitive effort they require (van Dijk & W. Kintsch, 1983). Such qualitative differences in strategy use are an important differentiator between skilled and less skilled learners and between persons with expertise in a particular discipline and those who have little domain knowledge.

Novices in a given domain tend to process new information in a straightforward linear fashion, while experts process more recursively, Using repeated passes through the material. Novices generate fewer inferences than experts, who enrich the incoming information with extensions from their own knowledge base. Novices generally attend more to the surface features of a problem or a situation than experts, who readily grasp the underlying principles or structure of a problem, or the important

points and overall significance of a discourse. Such differences have been consistently found across a wide variety of text processing and problem solving situations. However, much controversy revolves about the issue of whether there are general learning strategies that are independent of domain knowledge and whether these could be effectively taught to less skilled learners. Though this issue is still unresolved, some successful attempts to teach certain kinds of strategic knowledge make it possible to offer suggestions for designing instruction.

**Instruction:** A very successful technique in a number of studies with children has been to bring these mental activities out into the open, to make available to conscious inspection the hidden processes that enable an expert to surmount a comprehension or writing impasse, or to deal with a complicated problem. One way to do this is, of course, to offer explicit instruction on the use of appropriate cognitive strategies. Some studies have shown this to be successful with school age children, and surely discussing strategic knowledge with older learners can do no harm. However, research indicates that modeling of expert problem solving or text processing strategies in a particular problem situation may be even more effective, especially when learners are then allowed multiple opportunities to practice the strategies under the guidance of a skilled teacher (Brown & Palincsar, 1989; Scardamalia, Bereiter, & Steinbach, 1984). In particular, Bereiter and Scardamalia (1989) stress that strategy teaching alone is not sufficient; strategies must be learned in the service of meaningful goals.

### Metacognition

Metacognition, the ability to monitor one's own comprehension and to control strategic processing in performing a complex task, is a significant component of knowledge acquisition and knowledge use. The use of cognitive control strategies to monitor on-going comprehension or progress in solving a problem, to plan future processing, to redirect attention to problematic areas, and to deploy the appropriate remedial strategies has been singled out as a major distinguisher between the learning styles of younger and older students, between successful and less successful learners, as well as between those who have or lack expertise in a given domain (Glaser & Bassok, 1989). Much of the research on metacognition has dealt with individual and age related differences in reading comprehension within school age populations. Notable success has been documented by several programs designed to train metacognitive skills in children, most notably the reciprocal teaching method of Palincsar and Brown (1984). There are indications that deficiencies in metacognitive control over knowledge processing are also characteristic of older students who are poor learners. As yet little research has been directly concerned with this question, however, it is the topic of a proposal developed by the present author.

Nevertheless, considerable benefits to learning could be gained by designing learning environments around principles which have been found to maximize use of strategies for self directed, independent learning. This is the goal of Palincsar and Brown's reciprocal teaching program, and has become the focus of a major research effort, known as cognitive apprenticeship. This approach to learning, which is summarized in Collins, Brown, & Newman (1989), attempts to adapt methods that are effective in traditional apprenticeship settings to classroom instruction.

**Instruction:** The reciprocal teaching method was developed to instruct four comprehension monitoring strategies that are characteristic of skilled reading and that maximize the reader's active involvement in the content: formulating questions, summarizing, clarifying, and predicting. The justification for these strategies and the theoretical framework is presented in depth in Palincsar & Brown (1984) and Brown & Palincsar, (1989). The method has been adapted for training self-regulatory strategies in other domains and instructional settings, for example, to train reflective processes in writing (Scardamalia, Bereiter, & Steinbach, 1984), comprehension of science texts and word arithmetic problem solving by elementary school children (Scardamalia & Brown, work in progress), and to construct computer-supported intentional learning environments (Scardamalia, Bereiter, McLean, Swallow, & Woodruff, 1989). More generally, the key concepts on which these programs are based also overlap with those endorsed by the cognitive apprenticeship approach. They are the following:

(1) Opportunities are provided for learners to observe an expert modeling the processes necessary to perform a complex task. For example, thinking out loud is often used to externalize the largely unconscious strategies and control processes of an expert reader.

(2) The instructor guides the learners' attempts to apply the modeled activities to new material. This may take the form of offering hints, feedback that shapes a learner's response to bring it closer to an expert level, reminders, and new tasks (Collins et al., 1989).

(3) Scaffolding refers to providing supports that enable learners to use higher-level processes and to work on complex tasks that they would be unable to perform unaided. These may be in the form of verbal hints that prompt for the needed kind of information in writing or revising an essay (termed procedural facilitation by Scardamalia & Bereiter, 1985), or a graphic representation of the underlying structure of an algebra problem (e.g., W. Kintsch, 1989). The function of these supports is to reduce the memory load so that the student can concentrate on some of the critical elements of the task without being overwhelmed by the demands of the overall task. Thus, some part of the task is initially carried out by the teacher (or tutoring system), but the scaffolding or supports are gradually withdrawn

as learners internalize the appropriate strategies and become able to accomplish the task on their own.

(4) The notion of shared cognition, which refers to the social context of learning, is another crucial means of engaging students in knowledge use and productive learning. This is discussed below as a separate principle of learning.

### The Social Context of Learning

The acquisition of knowledge is supported by learning in a social setting. Embedding instruction in a group setting has several advantages, according to Brown and Palincsar (1989). (1) Cooperative learning provides a means of promoting the use of self-regulatory strategies in a group setting. Anxiety is reduced and motivation increased by having the responsibility for comprehending, solving a problem, or completing a task shared by all members of the groups. (2) More complex problems can be tackled in a collaborative group than a single individual could accomplish, since the work on subparts can be distributed across several individuals. (3) The activities are modelled at different levels and become externalized through discussion, with members contributing according to their abilities. (4) The collaborative group provides support for learners at different levels of expertise, enabling them to use skills that are just emerging. Resnick (1989) points out in addition that cooperative learning incorporates many of the advantages of traditional apprenticeship training in that it offers opportunities to experience knowledge in use, in contexts where the meaningfulness of individual elements of a task or activity to the whole is apparent to the learner. In so doing it counteracts the tendency of school learning (which is true even at higher academic levels) to break down into decontextualized rituals.

Instruction: Responsibility for knowledge building is shared across a whole class in a computer-supported intentional learning environment being developed by Scardamalia, Bereiter, and their colleagues (1989). Individual students contribute information, thoughts, ideas in several media (text, graphs, timelines, drawings) to a common database. The information is then available to everyone to comment on, expand, or incorporate into individual projects. This program draws on principles from cognitive theory and research to create computer-based supports for intentional learning: "environments that foster rather than presuppose the ability of students to exert intentional control over their own learning" (p.52). The reader is referred to the source cited above for a detailed description of the program, which represents one of the few attempts in the literature to design an unintelligent tutoring system (though see W. Kintsch, 1989, for related work). The core notion here is that the learner, rather than the computer, is put in control of learning processes, such as, setting goals, planning the route to accomplish them, monitoring progress, finding and correcting errors. The

computer's role is not directive, but instead provides various types of supports for these cognitively more demanding activities: for example, by presenting organizing structures, formats, and reminders for keeping track of information, narrowing choices through menus, storing and retrieving information. These computerized functions serve to reduce the memory load for the user.

### Higher-Level Thinking Processes

The ability to engage in higher level thinking depends on automaticity at lower levels of processing. Activities that fire automatically and knowledge units that are directly accessed require few processing resources, thus memory space becomes available to engage in inferential processing that requires conscious attention.

**Instruction:** There are two components to instruction implied by this principle, which correspond to the type of skill or competence that is being trained, or, according to some theories, the stage of skill acquisition. According to Anderson's (1987) ACT\* theory of learning, knowledge that is first acquired in a declarative form is transformed into a highly efficient proceduralized skill through extensive practice. Training programs (e.g., Anderson, Boyle, & Yost, 1985) are designed around models of successful problem solving, which make the procedures explicit to the learner. The environment is highly structured to keep the student on the correct solution path by providing feedback and correction during the problem solving process. Providing multiple opportunities for error-free practice is emphasized by Anderson and also by Schneider (1985) for developing automatic routines. In Schneider's research, the purpose is to allow for the effective interaction of automatic and consciously controlled processes (Glaser, 1988).

Memory load must be alleviated in programs developed to train self-regulatory and intentional learning strategies so that learners can approximate the higher-level comprehension and meaning interpretation of an expert. The idea of procedural facilitation - providing supports for more effortful, thinking processes - is central to the design of the learning environments described above in Section 7, especially the computer-based tutoring system of Scardamalia et al. (1989).

### Feedback Issues

Learning is enhanced through immediate qualitative feedback on process. This kind of feedback goes beyond the information that the solution was right or wrong, for example, by indicating to the learner what to change, how to go on, etc. However, there are differences of opinion among cognitive scientists concerning

the role of errors in the learning process, though again, these probably reflect differences in the kind of learning that is the focus of a particular instructional theory or training program. Extensive, error-free practice seems to facilitate automatization of procedural skills (e.g., Anderson et al., 1985; Schneider, 1985), whereas errors and conflicts can be used to drive learning of declarative knowledge. Errors and discrepancies between new and existing knowledge provide the motivation to go after more information in programs whose goal is to foster self regulation and self determination of learning goals.

**Instruction:** For either learning goal, the directive for designing instruction would be to provide feedback geared to the learner's present level of knowledge or skill. A related issue concerns the need for more qualitative assessment tools, especially when knowledge building and knowledge transformation are the focus of the instructional program. No specific recommendations are possible since research on theory based assessment measures has not kept pace with instruction.

#### Adapting Instruction to Skill Development

The content of instruction should be designed to fit the changing needs of students at different stages of skill acquisition (Lave, cited in Collins et al., 1989).

**Instruction:** Collins et al. propose three principles to guide the sequencing of tasks in order to facilitate the development of problem-solving skills. They might also be considered in deciding how to order the presentation of components of declarative knowledge. (1) Tasks should increase in complexity according to the amount of expert skill required (2) Sequencing should reflect increasing diversity in the types of strategies or skills used. (3) Present tasks airing global knowledge or skills before local ones so that students are encouraged to build a conceptual model of a problem before attending to the individual elements.

In summary, research in cognitive science suggests a need to design instruction within a theoretical account of how humans process information in complex cognitive tasks. According to this view, less emphasis is placed on the exposition of declarative knowledge than in the past. Classroom instruction needs to move away from the didactic approach as the primary vehicle for transmitting knowledge towards viewing learning as a problem-solving activity in which learner and instructor are collaborators in the shared task of constructing meaning.

#### IV. Cognitive Science Update of Instructional Systems Development Models (Tennyson)

Instructional design refers to a system of procedures to guide the development of learning environments. This systematic guidance is represented in the form of operational instructional systems development (ISD) models. Procedures defined in ISD models are, in large part, supported by instructional theories (i.e., theories which prescribe manipulations of instructional variables and conditions hypothesized to improve learning). Figure 1 illustrates the theoretical support of ISD models by linking instructional theory to learning theory.

Figure 1

LEARNING THEORY	INSTRUCTIONAL THEORY	ISD MODEL
Description of the Learning Process	Prescription of Instructional Variables to improve Learning	Procedures to Enhance Development of Learning Environment
BEHAVIORAL PARADIGM	BEHAVIORAL INSTRUCTIONAL PARADIGM	ISD PROCESS
S-R R	Small-steps Overt Behaviors Feedback Branching	-Behavioral Objectives -Pretest -Instructional activities -Posttest -Revisions



Figure 1 continued

COGNITIVE PARADIGM	COGNITIVE INSTRUCTIONAL PARADIGM	UPDATED ISD PROCESS
Information Processing	Knowledge Base	-Analysis
Perception	Pedagogy Base	-Design
Working Memory	Integrated Instruction	-Development
Long-term Memory	Diagnosis & Prescription	-Implementation
	Context (Situated cognition)	-Maintenance

Figure 1. Relationships among learning theory, instructional theory, and ISD models

#### Instructional Theory and ISD Models

Initially, ISD models were developed by the Department of Defense during World War II to improve the efficiency of certain types of high-level technical training programs (e.g., pilot training) (Reiser, 1987). By the mid-1950s, the first ISD models for the improvement of teaching were introduced. Skinner's (1954) notion of the behavioral paradigm for learning set the theoretical foundation for instructional theory and ISD models for the next two decades. Skinner proposed a concept for models of instructional design that consisted of formal and generalizable methods of instructional design supported by clearly defined principles of learning. Skinner (1963) and others (e.g., Crowder, 1959) defined the behavioral paradigm for instructional theory to contain the following three principles:

- Small incremental steps of content presentation
- Overt (active) learner responding
- Immediate reinforcement of correct responses

The following two principles, although in contradiction of the above principles, were added to account for situations in which students made errors and/or had multiple possible answers:

- Knowledge of results feedback on both correct and incorrect responses

- Branching in response to errors and/or mistakes

In summary, the behavioral paradigm for instructional theory maintained that learning of a task was basically the reinforcement of correct responses to given stimuli.

To assist in the preparation of appropriate instructional materials to improve learning, ISD models were constructed around general systems theory principles which identified a number of activities to be performed by an instructional designer. In one of the first ISD models, Glaser (1965) identified the following five interactive components:

- Writing behavioral objectives

- Preparing a pretest

- Organizing instructional activities

- Writing a posttest

- Making revisions

From that original set of procedures, ISD models rapidly expanded in basic components as educational technology advanced in the high technology areas of computer and video hardware. The growth of the models was, however, based solely on procedures thought to enhance development of instruction, not necessarily on the support of advancements in learning theory. That is, the ISD models grew in complexity independently of learning theory.

For example, Gropper (1983) added six ISD components to Glaser's original five as follows:

- Learner assessment (i.e., other measures beyond the pre- and posttests)

- Sequencing of goals and content

- Learner analysis

- Instructional strategies

- Media selection

- Implementation and maintenance

By the end of the 1970s, Andrews and Goodson (1980), in a review of ISD models, identified four more generally used ISD components. These were:

- Needs analysis
- Alternatives
- Constraints
- Costs

In all, Andrews and Goodson found over 60 different ISD models from which they selected 40 to review, using the ISD components listed above as comparison variables.

In summary, the initial ISD models directly exhibited the principles of behavioral learning theory in their principles of instruction. The growth in the models was not a direct result of developments in learning research but rather in ways to improve both efficiency of the development process and quality of the product. Thus, the ISD models development from two separate and independent fields: Initially, from the foundations of learning principles and, secondly, from standard systems theory. The first field provided the learning theory while from the second evolved process for product development.

The research and theory advances in cognitive science and instructional technology in the past two decades provide a means to update the learning theory foundation of ISD models. These developments also offer recommendations for changes and adjustments within the system itself. The purpose of this report is to update the basic ISD model in reference to its components and structure. The basis for this updating is founded in the developments offered by cognitive science (including here cognitive psychology and computer science) and instructional technology (see Table 1).

#### Overview of Changes

Beginning in the early 1970's, psychologists with an interest in classroom learning (e.g., McKeachie, 1973), began to discuss the shortcomings of the behavioral paradigm to the demands of real world learning needs. Offered as substitutes to the behavioral paradigm were learning theories proposed by cognitive psychologists. The description of the learning process shifted from the stimulus-response reinforcement paradigm to the acquisition, storage, and retrieval of knowledge paradigm (see Figure 1).

As a result of shifts in learning and instructional theories, the emphasis in instructional design procedures also gradually shifted from reinforcement of responses to the following:

- Organization of information (i.e., knowledge base)
- Ways to improve acquisition of information (i.e., pedagogy base)
- Correct knowledge representations in memory.

Examples of the effect of the learning paradigm shift can be seen in how it has influenced several instructional theories. Gagne's instructional theory, as embedded in his conditions of learning, shows a profound transformation from a behavioral paradigm with emphasis on associative and assimilation theory (Gagne, 1970) to a cognitive theory with concern for the understanding of internal processes of learning and thinking (Gagne, 1985).

Merrill's work, likewise, reflects a direct shift in underlying learning theory in his approach to ISD model development. In his Component Display Theory (Merrill, 1986), Merrill drops the notion of behavioral objectives in favor of such components as a student model (knowledge stored in memory) and a knowledge base (domain of information).

In another example, Tennyson's instructional theory makes a direct trace of each of eight instructional variables through the knowledge base to specific learning processes (Tennyson & Cocchiarella, 1986). More recently, Tennyson has expanded his view of the types of knowledge stored in memory to include not only declarative (knowing that) and procedural (knowing how) knowledge but also contextual knowledge (knowing when and why) (Tennyson and Rasch, 1988). His instructional theory links cognitive processes directly with specific instructional strategies. The instructional strategies range from expository presentations (to improve declarative knowledge) to self-directed strategies (to improve creative processes).

During the same time period, educational technologists were focusing their work on the direct interaction of technology attributes with learning and instruction (e.g., Salomon, 1985). Because of the learning paradigm shift, instructional technologists became increasingly concerned with the "why" of media in the improvement of learning as well as the "how" (Clark, 1983). This interest was accelerated with the rapid growth of microcomputers starting in the late 1970s.

An emerging paradox in educational technology is the fear that the exciting advances in hardware and software would dominate the ISD process to the exclusion of other concerns. For example, in applications of artificial intelligence (AI) methods to instructional computing, the focus has been on software intelligence. The technology emphasis by ICAI developers has tended to reduce the attention given to most other educational concerns of ISD in favor of simple instructional methods and strategies (Park, Seidel, & Perez, 1987). However, the potential impact of educational technology on the ISD process is readily seen in several areas. There include methods of information analysis (e.g., expert systems), learner interaction with media (e.g., mixed initiative, natural language dialogue), means of learner assessment during learning (e.g., error analysis in diagnosis), and control of the learning environment (e.g., learner control, advisement, coaching).

#### Comparison of Baseline ISD Model and Updated ISD Model

ISD models are the means by which educators have been able to apply new research findings and theories in learning and instruction to the improvement of learning. Many of the current changes in the ISD process come as a reactive process of updating an established set of ISD principles. Developments in the fields of cognitive psychology, computer science, and instructional technology have greatly expanded the complexity of the ISD process in the continuing effort of educators to improve the effectiveness and efficiency of learning through enhancement of the instructional process. The updated ISD model presented in this report represents a most current effort in this on-going process of ISD model evolution. In Table 1, I present a comparison of the proposed updated ISD model with a generic ISD model.

Table 1

#### Comparison of Baseline and Updated

#### Instructional Systems Design (ISD) Models

##### PHASE 1: ANALYSIS

##### Baseline ISD Model

- Define Training Requirements
- Analyze Training Needs
- Define Needs and Constraints
- Analyze target Population
- Define Media Requirements
- Establish Expected Performance Levels
- Document General Course Specifications

Table 1 (continued)

Survey Existing Resources  
Plan Design and Development Effort

Updated ISD Model

Front End Analysis  
Define Philosophy and Theory of Learning Conditions  
Analyze Learning Needs and/or Problem  
Define Learning Variables  
Define Constraints on Resolution of Learning  
and Performance Discrepancies  
Analyze Target Population  
Define the Learning Environment  
Specify Goals  
Analyze Domain of Information  
Define Management and Delivery System  
Define Conditions of Learner Assessment/Evaluation  
Define Situational Variables  
Define Specifications of Learning Program  
Feasibility Evaluation  
Plan Design and Development Effort

PHASE 2: DESIGN

Baseline ISD Model

Perform Instructional Task Analysis  
Specify Instructional Objectives  
Define Entry Behaviors  
Group and Sequence Objectives  
Specify Assessment System  
Specify Evaluation System  
Review/Select Existing Materials

Updated ISD Model

Specify Instructional Objectives  
Analyze Instructional Information Structure  
Define Entry Knowledge  
Define Organization and Sequence of Information  
Specify Learning System  
Specify Message Design  
Specify Human Factors  
Specify Learner Evaluation System  
Specify Formative Evaluation System  
Review/Select Existing Materials  
Prepare Design Document

Table 1 (continued)

PHASE 3: DEVELOPMENT

Baseline ISD Model

- Prepare Content Narratives
- Prepare Learning Activity Designs
- Develop Learning Activities
- Develop Test Items
- Reviews
- Editing
- Formative Evaluation
- Final Edit and Composition

Updated ISD Model

- Prepare Content Narratives
- Prepare Learning Activity Designs
- Develop Learning Activities
- Develop Assessment Instrument
- Reviews
- Editing of Learning Program
- Formative Evaluation
- Documentation

PHASE 4: IMPLEMENTATION

Baseline ISD Model

Updated ISD Model

PHASE 5: MAINTENANCE

Baseline ISD Model

- Summative Evaluation

Updated ISD Model

Phases of Instructional Systems Design

Instruction is a process that involves both the planning of an environment where learning can take place and the delivery of information to the learner. How to improve learning in a planned environment has been a major concern of educational psychologists since the first formal research on classroom by Edward L. Thorndike (1914). Since Thorndike, learning in the classroom (or training) environment has been a focus of educational psychologists who must consider the complexity of factors that influence the effectiveness and efficiency of classroom instruction.

Factors that contribute to the divergence in student learning include cognitive and affective variables, student knowledge, stimulus properties, delivery systems (e.g., lecture, computer, video, etc.), management procedures (e.g., program control, learner control, adaptive control), instructional strategies and evaluation methods.

Although educational psychologists, as well as other educators, have long dealt with these factors, it has only been in the past decade that they have investigated variables and conditions directly related to the planning of a total learning environment; that is, recognizing the interaction of multiple factors that go into designing and implementing instruction. As stated in the introduction to this report, ISD is the term applied to this planning effort; it includes the processes of development, evaluation, and management. The ISD concept of development employs a scientific process that involves both the planning of the environment where learning can take place and the delivery of information to the learner.

Recently, the growth of the ISD approach has been facilitated by major inputs from fields of inquiry outside of education, such as computer science, management information sciences, and psychology; and within the field especially from instructional technology. Whenever possible, research and theory from these areas have been applied to appropriate phases in the proposed updated ISD model. Contributions from computer science include system design strategy variables (e.g., system architecture and software developments), structure of information (both as external information and internal representations), efficiency of design concepts (e.g., heuristic methods), and alternative learner control methods. From psychology, contributions include models of human processing (especially for higher order thinking), representation of knowledge in memory, employment of knowledge in the service of higher order situations (e.g., problem solving), measurement of higher order processing, and others. Contributions from instructional technology range from systems theory development to employment of graphics and visuals to instructional strategies.

In the proposed updated ISD model, I emphasize the basic principles of design using an iterative approach to development rather than a conventional algorithmic process model in which the output of one step becomes the input for the next. I do this for two reasons. First, the complexity of the ISD process is a result of alternatives available for solving domain-specific learning problems. Thus, within the instructional design phases the author has numerous options to be considered and organized to fit the given situation. Second the authoring activities can be independent of the decision making. For example, in the design of an expert instructional design system, the knowledge base can be separate from an executive control strategy system.



The principles of design in the proposed updated ISD model are based primarily upon learning and instructional research and theory and, of equal importance, upon applied ISD experience. It is one thing to talk and write about the instructional design process, and quite another to have actually done it. As a design science field, much like engineering, instructional design relies upon field experience for much of the "how to do it" components of its system. In this regard, the phases exhibit different degrees of theory and empirical base. For example, the analysis phase draws heavily on learning theory to set the conditions of learning and evaluation. In contrast, the development phase draws on field experience to define activities.

Another important trend toward a scientific approach to instructional design is the increased emphasis placed on the use of evaluation (Tennyson, 1978). Although evaluation has always been part of the ISD plan, it traditionally was relegated to the last step in the process. Even the most recent models (e.g., Merrill, 1983; Reigeluth, 1983) have only a minimal consideration of evaluation. The impetus for increased employment of evaluation in development is part of a larger societal movement towards accountability in education and training. Following the guidelines presented by Tennyson's theory-based model (Tennyson, 1977), I have made evaluation an integral part of each phase of the updated ISD model.

The various phases of the ISD model--Analysis, Design, Development, Implementation, and Maintenance--will be presented in five sections. The purpose this report is twofold: First, to operationally define and elaborate the ISD phases (with an emphasis on the proposed updates); and, second, to discuss authoring activities (within the context of Air Force technical instructors) that might be associated with future development of the Advanced Instructional Design Advisor (AIDA).

### Analysis Phase

Instructional development begins with an analysis of the learning environment to determine if an instructional need or problem exists. This environment is assessed to provide data to answer the question, "would an instructional development effort be feasible and desirable?" This activity defines the conditions and parameters of the problem from which specifications for the instructional development project can be proposed. The procedures and findings of the analysis phase are evaluated for the purpose of determining one of the following decisions:

- Adopt currently available instructional materials,
- Modify existing instruction, or

-Develop new instructional materials.

If either of the latter two decisions is selected, then the instructional development would follow through the remaining phases. Selection of the first decision, to adopt, would require only the implementation phase.

The analysis phase includes the following five processes (Table 2):

- Front-end analysis of the learning problem (e.g., learning philosophy and theory, analysis problem, initial analysis of domain, possible constraints),
- Definition of situational variables,
- Definition of learning problem specifications,
- Plan for the development effort.

Authoring activities and the nature of ISD model updates for the Analysis Phase are discussed below.

#### Front-end Analysis

A learning problem is usually assessed and defined in terms of curricular needs and goals. A curricular (or macro) level analysis establishes the learning need(s) and/or problem(s) in the context of a total learning environment. Too often instructional development has been done entirely at the instructional (or micro) level with little concern to connections or linkages to other information within or external to the given domain. However, the theories of cognitive psychology directly relate to the structure of domains of information to bridge the gap between knowledge stored in memory and information to be learned (e.g., Mandler, 1979). The development of knowledge representation concepts in expert systems also demonstrate the need to consider the total structure of information within and among domains.

Philosophy and theory of learning. To design instruction that can predictably improve learning, it is important first to specify (a) a philosophy of the educational environment in terms of the role and scope of the participants and setting; and, (b) the learning theory on which the instructional methods and strategies are based. This concept has been and is fundamental to instructional theories. Some examples of this are as follows:

- Thorndike's initial application of behavioral theory in the philosophy of the classroom by recommending classroom teaching methods on the two laws of effect and exercise. The notion of the child as responding to controlled manipulations for learning was in direct contrast to the

functional philosophy that humans adapted to their environment by internal control.

-An extension of Thorndike's philosophy and theory of learning was Pressey's teaching machine. Pressey's mechanical device, which used a keyboard, presented a series of multiple-choice questions and required the student to respond by pressing the appropriate key. If the student pressed the correct key, the device would present the next question. However, if the student pressed an incorrect key, the device would ask the student to choose another answer without advancing to the next question. If the student correctly answered two questions in succession, mastery was assigned, and no additional questions from that objective were given. The device also recorded responses to determine whether the student needed more instruction to master the objective, consequently it made use of a modified form of the law of exercise.

-Skinner's contributions to instructional theory were reviewed briefly in the introduction to this report. Skinner's philosophy is well documented in several popular style books. His book, Walden Two, is an explicit statement of the behavioral paradigm as might be applied to a learning environment. It clearly discusses the role the teacher and how students learn. However, even with the prolific writings of Skinner in both theoretical and applied terms, there was a reaction to an instructional theory that was based on such a restricted view of learning. Application of the behavioral paradigm produced instruction that was often too fragmented and laborious. Attempts to correct the basic behavioral paradigm are seen in Crowder's contributions.

-Crowder's intrinsic programming allowed the more able learners to branch more quickly through the instruction while providing corrective frames for those who missed a question. And, although Crowder or others did not reveal an underlying learning theory or empirical evidence to support the branching technique, it became the design strategy for computer-assisted instruction; especially for drill and practice and tutorial methods.

Given contemporary cognitive psychology theories that view the learner as a thinking individual, capable of internal control and manipulations of knowledge, an initial activity in this ISD model update is to once again clarify the nature of the learner. A parallel activity is the definition of a learning theory which accounts for both the "why" and "how" of the learning process. The important design concept emphasized here is that an operationally defined theory of learning underlies the decision-making philosophy throughout the entire ISD process.

Analyze learning need(s) and/or problem(s). An important contribution of cognitive science to ISD is the concept that a need or problem is part of macro environment. Typically, ISD models have failed to integrate curricular design variables into the development of instruction, resulting in instructional programs that fail to identify the connections among the various domains of information in a given curriculum. From a cognitive psychology standpoint, it should be possible to trace each instructional activity back through the curricular system to specific needs and goals of the curriculum.

Assessment methods used in the specification of the learning need/problem are still for the most part qualitative, but the trend is toward obtaining data from quantitative sources; for example, surveys, job analyses, competency analyses, and curricular goal analysis. For example, in the Air Force environment, such data can be acquired and interpreted by analyzing the training curriculum, Air Force educational policies, other governmental regulations, and educationally related research and theory. The learning need/problem analysis process should provide data that specifies the needed information and objectives to be learned within a given segment of the curriculum.

Define learning variables. An initial step in understanding what is to be learned in reference to the learning need/problem is to specify the most abstract level(s) of knowledge employment within the domains of a curriculum. This technique of analysis is adopted from the field of knowledge engineering. The purpose is to determine "how" and "why" knowledge when a proposed curriculum is employed. Such employment can range from simple recall and recognition to high levels of complex problem solving and decision making. This analysis can provide an initial means for understanding the organization of a knowledge base. The educational outcome of defining the learning variables is to see the potential relationships between domains that have often been artificially separated and ignored.

Define learning constraints. The purpose of this component is to extend the above analyses in terms of the scope of the learning need/problem. That is, does the situation call for (a) a curricular level activity (e.g., setting up a new domain of information), or (b) a course level activity that is either embedded within a curriculum or exists as a single entity, or (c) a unit within a course, or (d) a lesson within a unit, or (e) a module within a lesson? This analysis puts parameters around the scope of the ISD effort in reference to the information to be learned. Again, this analysis is adapted from knowledge engineering methods.

Analyze target population. Educational and psychological research has demonstrated that instruction should be based on an analysis of the target population. The assumption is that learning can be improved if the instruction can be adapted to learner characteristics and learner differences. This analysis provides for a macro level student model in reference to these two categories: learner characteristics and learner differences.

Learner characteristics include such demographic variables as age, gender, cultural background, geographic location, and number of students. Learner characteristics define the nature of the target population as an integral entity.

Associated with the above analysis is a comprehensive assessment of learners to identify individual difference variables that might influence the conditions of instruction. Individual differences include cognitive variables (e.g., aptitude, intelligence, cognitive styles, learning styles), affective variables (e.g., motivation, personality factors, perception), and knowledge stored in memory. These individual differences constitute the elements of a student model at the macro level. In this analysis phase, consideration is on learner trait differences while in the design phase, state differences are analyzed.

#### Define the Learning Environment

The ISD activities discussed above identify the learning need/problem within a curricular level context. Within the Air Force training environment, many of the ISD activities would already be embedded within a defined curriculum and would be transparent to a given instructor (author).

This next set of ISD activities would involve much more direct interface between an author and an expert instructional design system (of the sort proposed in the AIDA program). The purpose of these macro level activities is to establish the scope and parameters of the ISD process to solve the given learning need/problem.

Specify goals. The front-end analyses provide the information necessary to specify the goals of the learning environment. In general terms, cognitive psychology offers two basic sets of goals: Those dealing with the acquisition of knowledge (e.g., declarative, procedural, and contextual) and the those with the employment of knowledge (e.g., cognitive complexity--recall and problem solving--and creative processes. Identifying forms of knowledge acquisition and employment at this point will help authors select appropriate instructional strategies during the Design Phase.

Analyze domain of information. In the past decade, the analysis of content within a domain of information has been one of the areas of ISD most influenced by cognitive psychology and artificial intelligence (Reigeluth, Merrill, & Bunderson, 1978). In the behavioral paradigm, the term "content analysis" is widely used to refer to the analysis and organization of subject matter based on the relationships of content attributes (see Reigeluth, 1983). In practice, the outcome of a content analysis takes on the appearance of either: a taxonomy (which structures information based relationships of critical features and/or superordinate and subordinate relationships) or some sort of network structure (which is organized around contextual cues and has no formal levels of abstraction).

However, in the cognitive paradigm, knowledge exists in memory as part of larger, more complex associative networks. Therefore, it is appropriate in organizing information for learning that consideration be given to how the domain-specific information may be stored and retrieved from memory, especially in the service of problem solving.

In complex cognitive situations, knowledge needs to be retrieved from long-term memory and manipulated in working memory in ways not originally encoded. This process of retrieving knowledge for complex employment, unlike direct recall of declarative and procedural knowledge, implies the encoding of knowledge in reference to the organization and accessibility of knowledge in memory. In addition to a conventional content analysis at the curricular level, an extension of the learning variables analysis would seem appropriate following the cognitive paradigm.

The analysis of a domain of information using a cognitive paradigm has been facilitated by work in artificial intelligence on expert system knowledge bases. Although encoding and storage of content attributes are important, the primary goal of expert systems is with regard to problem solving and/or decision making. As mentioned earlier, knowledge engineering techniques have been used to describe procedures for obtaining information of how knowledge is employed in domain-specific problems. A knowledge engineer (KE) is someone specifically trained to extract from experts domain problems and strategies employed to solve problems thereby identifying the concepts (or rules, principles, facts) and associations of those concepts in solving problems. The resulting associations provide the basis for structuring an expert system's knowledge base. The strategies form the production rules of the expert system.

For curriculum development, the initial concern is the possible organization of the information for sequence presentation. The view from cognitive science is that knowledge per se is artificial, therefore, in meeting goals dealing with employment of knowledge, the curriculum should be organized

according associations rather than content attributes. Furthermore, in the Analysis Phase, the information organization needs only to be specified at its most abstract level. Later, during the Design Phase, the information would be elaborated in detail and would be augmented to account for the differences between the learner and the expert.

Define management and delivery system. The contributions of cognitive science and instructional technology in this component are only now being considered in ISD. In the area of management, computer-based management systems have had minimal application in direct instruction. Applications are primarily in administrative duties (e.g., grading and scheduling) and prototype computer-based instruction projects. Authoring activities in this component establish the means for managing the learning environment. Within the context of the Air Force technical training and AIDA, management techniques could range from conventional record keeping to possible computer-based instructional systems employing some type of intelligence. AI techniques are still only at the prototype stage, but educational research in adaptive programs using AI methods might be available, especially if integrated into authoring systems.

Recent research in instructional technology on graphics and visuals is in direct contrast to earlier findings on the role irrelevant features in learning from drawings. The enriched screen capabilities of computers provide displays that can more clearly represent information in meaningful contextual forms. That is, knowledge representation includes not only relevant features of information, but also so-called irrelevant features. However, in the context of cognitive psychology, nothing is considered irrelevant and, in fact, what is labelled irrelevant is often the necessary information for both storage and retrieval of information. Of special interest for the Air Force is the improved representation of dynamic information offered by computers. The use of simulations for direct technical training would certainly be enhanced by delivery systems that reduce transmediation effects.

The concern for the author at this point in the curriculum phase, is to be aware of the effect of transmediation on learning and to consider delivery systems that improve representation of the information. Associated with delivery system selection is the concept of cost-effectiveness. Cost-effective analysis attempts to balance improvements in learning with costs of delivery. Costs per student hour of instruction can adjust somewhat, but such a determination should be part of the final decision plan.

Define learner assessment and evaluation. Progress in the field of student measurement and testing has been a continuing weak point in education. Measurement theory and practice seems not to be affected by the growth of cognitive psychology. That this is a continuing problem is seen by the inability of cognitive psychologists to adequately test their assumptions about higher-order cognitive skills and strategies. Measurement and testing still features the absolute standard procedures of assessing declarative and procedural knowledge, with most measures of higher-order cognitive activities focusing on domain-independent knowledge. Instruments designed to test inference making only deal with "general" knowledge types of measures. The area should be a major focus of future research for the Air Force technical training command. The research should depart from the usual practice of both measuring domain declarative and procedural knowledge and generic inference making by investigating variables and conditions for testing and evaluating domain-specific higher-cognitive processing.

Define Situational Variables. An integral activity in the Analysis Phase is an assessment of the resources and facilities of the learning environment. These include not only the instructional resources of the learning but also the resource capabilities (i.e., facilities, funding, and staff) for doing the instructional development. Though it is important to maximize instructional resources, constraints inherent in those resources must also be recognized. The concept of constraints implies both the physical limitations and the capabilities of the resources for improving learning. The analysis of the situational variables should provide information on the characteristics of the learning environment, that is the potential learning and instructional capabilities of the available resources and facilities, and the requirements for modification and development activities. Contributions by instructional technology in this area are primarily in identifying procedures to improve methods of evaluation. For example, Merrill and Wood (1975) developed a quantitative procedure for evaluating existing instructional materials based on such variables as structure of the information, the student model, and the instructional strategy. Future work might exhibit quantitative procedures associated with the developments in cognitive science discussed in this proposed updated ISD model.

An important consideration for the development of the AIDA would be to include features that would aid an author in identifying existing materials and comparing those with the learning needs and problems. Additionally, the AIDA could aid authors in identifying source manuals, subject matter experts, and other appropriate resource people.



Define Specifications of the Learning Program. The above set of analysis activities provide the necessary information to specify the variables and conditions of the learning program. This information should be put into a document to specify the following:

- Length of the curriculum or course in terms of years, months, days, and hours.
- Structure of the information to be learned.
- Proportion of instruction presented by allowable media.
- Description of the target audience (i.e., learner characteristics and differences).
- Definition of learning environment constraints (i.e., curriculum, unit, course, lesson, or module).
- Specification of the goals and information to be included.
- Selection of management and delivery systems.
- Specification of the situational variables.

Feasibility Evaluation. The purpose of this front-end evaluation is to document the feasibility of carrying out one of three types of instructional development (i.e., adopting, modifying, and developing) given the specifications derived from assessments and evaluations in the Analysis Phase. As such, feasibility evaluation focuses on documenting both the validation of the analysis procedures and the rationale of the specifications; that is, complete information should be provided on how the data were collected, from whom they were collected, and what method of validation was employed. For example, if data were collected from training personnel (or other identifiable military group), were they surveyed with constructed response instruments or questioned about their opinions; if data were from military contractors, were individuals or representatives from organizations contacted; or if data were from military educational policies, were the policies consistent with known research findings or desired results? Much of this documentation in the feasibility evaluation could be part of the AIDA system.

Documentation should also demonstrate how the goals directly relate to the specifications derived from assessing the learning need/problem, the learners, the domain of information, and the situational variables., For example, if a job analysis survey in a specific military task was conducted, the findings could be reviewed by experts of that given task. Analysis procedures are evaluated and documented in terms of their

proximity to standard methodology and consistency of the data interpretation.

An additional form of evaluation involves an analysis of the likelihood that a developmental effort would result in a product which justifies the estimated expenditures in time and resources. In conventional practice, most cost-estimation procedures used in instructional development are designed for either summative evaluation or for continuing use of the product. However, by updating the ISD process with contemporary principles of cost-effectiveness (e.g., Doughty, 1986), which include direct costs and learning effectiveness, it would be possible to establish more precise cost-evaluation data in the Analysis Phase. Again this would be quite feasible in the proposed AIDA system.

### Instructional Design Decision.

It is at this point the ISD process that the decision can be made as to how to proceed in solving the learning need/problem. One form of documenting this solution is to prepare a proposal that states the rationale for the instructional development decision and specifications for accomplishing the stated goals.

### Design Phase

The second phase in the proposed updated ISD model deals directly with the design of the instruction. Design is the area of ISD that has received the most research attention and most theoretical development; yet it is probably the least employed phase in instructional development. This paradox occurs because of the division of work and interest between the researcher and the developer (i.e., the author).

The failure to apply research findings is probably due more to the increasing complexity of the ISD process than to unwillingness by developers to use research findings. An analogy here is the health sciences field in which expert systems are seen as means to aid the health practitioner in avoiding bias and in employing updated methods in both diagnosis and prescription processes. Likewise, the concept of AIDA is to provide the Air Force instructor with a means of developing quality instruction within the increasingly complex ISD process.

The Design Phase functions to bridge the gap between the curriculum level specifications of the Analysis Phase and the actual production of the instruction in the Development Phase. Eleven activities are proposed in the Design Phase (Table 2):

- Specification of learning objectives

- Analysis of the information to be learned
- Definition of the entry knowledge
- Definition of the organization and sequence of the information
- Specification of the message design
- Specification of human factors
- Specification of the learner evaluation system
- Specification of the formative evaluation plan
- Review of existing materials
- Preparation of a development plan

Table 2

Authoring Activities in the Analysis Phase

Analysis Phase Steps	Authoring Activities
Front-end analysis	Establish conditions of the learning environment
Define philosophy and theory of learning conditions	These conditions influence each stem in the ID process. Thus, the generic steps are adjusted to account for the defined conditions.
Analyze learning needs and/or problem	Identify discrepancies between desired and actual learning and performance discrepancies
Define learning variables	Identify specific information to be learned
Define constraints restricting resolution of learning and performance discrepancies	Identify the scope of the need/problem (i.e., curriculum, course, module and/or lesson)
Analyze target population	Determine learner characteristics: geographic location, age

Table 2 (continued)

Authoring Activities in the Analysis Phase

	<p>ability, need for motivation, present skill levels, number of students Determine learner differences: Cognitive style, aptitude, learning style, personality factors, motivation, perception</p>
Define the learning environment	<p>Establish scope and constraints of the ID process</p>
Specify goals	<p>State abstract descriptions of what knowledge is to be acquired (levels of knowledge-declarative, conceptual, and procedural)</p>
Analyze domain of information (curriculum and course levels)	<p>Knowledge engineering activities: Identify organization of information Establish knowledge base</p>
Define management and delivery system	<p>Establish role of computer in management of the learning environment: Identify basic goals for computer delivery of instruction (and identify alternative systems, e.g. interactive video)</p>
Define conditions of learner assessment/evaluation	<p>Determine the method(s) for assessing and evaluating learner knowledge acquisition (e.g., methods of diagnosis, error detection, error analysis)</p>
Define situational variables	<p>Identify existing materials, compare them with needs/problem; Identify source manuals, subject matter experts, and resource people</p>

Table 2 (continued)

Authoring Activities in the Analysis Phase

Define specifications of learning program	Document conditions and specifications of program: length, structure, proportion presented by allowable media, target population description, definition of constraints, goals and information to be covered, levels of program intelligence within management and instructional system
	Validate the analysis process
Feasibility evaluation	Consider whether to: Buy use existing materials, modify an existing course, develop a new course, or discontinue development effort Estimate cost and resource requirements for each alternative

Specify Learning Objectives

An initial activity in the Design Phase is to define the learning objectives as they relate to the goals of the curriculum. Learning objectives received an influential position in ISD models under the behavioral paradigm. Likewise, the cognitive paradigm views objectives as an integral component of the updated ISD model. Learning objectives define the type of learning desired within the scope of the appropriate goals associated with knowledge acquisition and employment. In contrast to behavioral objectives which define end-of-instruction learning outcomes, learning objectives define the type of knowledge and cognitive abilities to be acquired. Learning objectives are important in the planning of integrated instructional environments because they provide the means of both allocating learning time and identifying specific instructional methods. Also, unlike behavioral objectives which only state observable learning outcomes, learning objectives imply a given cognitive process of learning or thinking.

The approach to writing objectives under the behavioral paradigm is well defined in many instructional development sources. Although most behavioral objectives follow Bloom's (1956) taxonomy, actual practice rarely dealt with behaviors above the application level because of the problem of direct observation of analysis, synthesis, and evaluation. Therefore, a major updating of the ISD model requires the recognition that higher-order learning objectives can be defined. A convenient way of doing this is to update Gagne's conditions of learning which already reflect this transition from the behavioral paradigm to the cognitive.

In terms of learner assessment, the cognitive-based objectives that deal directly with the acquisition of declarative and procedural knowledge provide for quantitative measures of specific domain information. However, the learning objectives for contextual knowledge acquisition and improvements in thinking are more subject to reflective evaluations rather than the usual correct or incorrect assessments associated with the learning of content information. That is, it is far easier to test a knowledge base for amount of information than it is to measure for organization and accessibility.

The categories of learning objectives presented here are for the most part taken from Gagne's (1985) classification of learning outcomes. Whereas Gagne prefers to lump all thinking processes into one category of human capability (i.e., cognitive strategies), proposed is a category system of learning objectives that provides for more basic distinctions among the various forms of thinking. This allows for clarification of both learning outcomes and instructional strategies, and allows a direct correspondence to be established among memory system components, learning objectives, and learning time. The proposed categories of learning objectives are as follows:

-Verbal information. This category of objectives deals with the learner acquiring an awareness and understanding of the facts, concepts, rules, and principles within a specified domain of information (i.e., declarative knowledge). The specific concepts to be learned are identified by an information analysis procedure that shows the schematic organization of the domain as well as the individual concepts.

An analysis of the information to be learned is a highly important procedure in instructional design, because it provides the instructional sequence by which information can be presented (Reigeluth, 1987). That is, a structured sequence enhances the learner's initial organization of a knowledge base (see Tennyson, 1981, for a complete review of an information analysis).

-Intellectual skills. This category of objectives involves the learner acquiring the skill to use correctly the concepts, rules, and principles of a specified domain of information (i.e., procedural knowledge). The classification of unencountered examples of a given concept is an example. Classification is the intellectual skill by which learners both discriminate and generalize to previously unencountered examples. The intellectual skill for rule using, is the ability to use the rule correctly in the solving of a previously unencountered problem.

-Contextual skills. This category of objectives focuses on the learner's acquisition of the organization and accessibility of a knowledge base for a particular domain (i.e., contextual knowledge). The organization of a knowledge base refers to the schematic structure of the information, whereas accessibility refers to the cognitive skills that provide the means for employing the knowledge base in the service of recall, problem solving, and creativity. Contextual knowledge includes the criteria, (i.e., standards, values, and appropriateness) of a given domain's structure. For example, simply knowing how to classify examples or knowing how to use a rule (or principle) does not imply that the learner knows when and why to employ specific concepts or rules. Therefore, this objective category requires a learning environment in which the learner can develop both the associative network of the knowledge base (i.e. organization) and the skills to effectively employ the knowledge (i.e., accessibility).

-Cognitive strategies. This category of objectives deals with both the development of cognitive complexity abilities and the improvement of domain specific skills of thinking. Cognitive strategies objectives deal with two important issues in education. First, is the elaboration of cognitive strategies that will arm the students with increased domain specific contextual knowledge. As stated earlier, thinking processes (i.e., recall, problem solving, and creativity) are domain-independent and are only integrated within domains as skills by employment on domain-centered situations. For example, knowing the scientific method of inquiry (an abstract set of concepts) does not in and of itself provide sufficient information to transfer across disciplines without the further acquisition of more concrete domain-dependent application skills. A second role of cognitive strategies objectives is the development of the cognitive abilities of differentiation and integration. These abilities enable learners to effectively employ and improve the knowledge base; therefore, they are integral to any educational goal seeking to improve thinking strategies.

-Creative processes. This category of objectives deals directly with the most elusive goal of education, the development and improvement of creativity. The creative process can be

defined as a twofold ability: First, as the ability to create knowledge to solve a problem derived from the external environment; and, second, as the ability to create the problem as well as the knowledge to solve it. Integral to the creating of both the problem and knowledge is the consistency of the individual in employing appropriate selection criteria in evaluating possible problems and new information. In this process of cognitive evaluation, I define two forms of criteria. The first is criteria that are currently part of the knowledge base and which can be applied with a high level of consistency. In contrast are criteria that are developed concurrently with the problem and/or knowledge, and are consistently applied within the given situation or domain. Creative process objectives need to specify not only the ability to develop and improve creativity but also the form of criteria for evaluating creativity. That is, students should be informed of the criteria in the former and, in the latter, the necessity to develop criteria.

Gagne's two other conditions of learning, attitude and motor skill, refer in the former condition to affective processes and in the latter to psychomotor processes. For example, at the curricular level of learner assessment, the student model may indicate a motivational problem; in such, situations the instructional design could deal with the problem. In other situations, attitude may be an important curricular goal, therefore, it would be specified here as an affective objective and appropriate instructional variables would be specified within a prescribed instructional strategy.

If the learning need/problem indicated a motor skills goal(s), a learning objective for a motor skill process would be specified and a corresponding instructional strategy would be selected. However, minimal research work has been done with the interaction of motor skills and cognitive skills. Some applied work in pilot training using simulations has been done (e.g., Anderson & Trollip, 1981), but few generalizable variables have resulted from this work.

In summary, the ISD process of specifying learning objectives can be updated by extending Gagne's conditions of learning in the cognitive strategies area. Such an extension would also enhance the linkage between higher-order objectives and specific instructional strategies.

### Analyze Information Organization

The design of instruction ultimately centers on the information to be learned and the learning processes required of the learner in regard to given goals. This activity of the Design Phase refers to the analysis of the information to be learned. As discussed in the Analysis Phase, the behavioral paradigm for an analysis consists mainly of a flow-charting of



tasks in terms of behavior statements or content attribute statements or combinations of both. Instructional developers, as well as cognitive researchers, have found that the behavioral paradigm of organizing information is an inadequate structure for an efficient learning sequence. For example, because of the programming difficulties arising from the design of computer-based courseware, instructional developers have adapted the concepts of artificial intelligence to analysis of information (Simon, 1980). Bunderson (1983) proposed that when designing instruction, the information can be analyzed to determine the most efficient arrangement of the knowledge for purposes of learning not for purposes of disciplined organization (as in the knowledge base of an expert system).

Employing approaches of cognitive psychologists who have investigated knowledge representation in memory, I have updated the information analysis activity by elaborating from the abstract knowledge base defined in the Analysis Phase. Using the current cognitive paradigm of schematic representation, I propose three forms of elaborated analysis within the information analysis process. The first form, attribute characteristics, refers to the identification of specific concepts within a domain and the specific features of each concept (i.e., declarative knowledge). For example, within the domain of English grammar is the information associated with internal punctuation. An attribute characteristics analysis would identify the specific punctuation rules and their specific features. Such an identification would provide a basis for preparing the semantic structure (the second form of analysis) of the specific rules, based in part on their connections to prerequisite knowledge. The third form of analysis, schematic structure, identifies the connections within and among the schemata of a given domain of information. This analysis follows KE methods of identifying problems and problem sets and the schemes employed to solve the problems. The purpose of the schematic analysis is to determine the sequence of the information presentation. The sequence arms the learner with an initial organization of the information for solving problems. With additional experience in knowledge employment, the initial organization will be elaborated.

#### Define Entry Knowledge

An important contribution of the behavioral paradigm to instructional design has been the notion of aptitude treatment interaction (ATI). Briefly, this concept implies that within a given aptitude certain learners would learn better with a particular instructional method than other learners with a radically different measurement. For example, students with a high aptitude for mathematics would do better with a particular treatment, while students with a low aptitude would do better with an entirely different treatment. Unfortunately, the ATI approach to individual differences has not been shown to

effective in improving learning. One basic problem was that the general aptitude measure was not a good means for prescribing specific instructional treatments. On the other hand, the cognitive paradigm of making connections between information to be learned with prerequisite knowledge stored in memory has been shown to be a more effective means of prescribing instruction.

Proposed in this updated ISD activity, is the specification of necessary entry knowledge that a learner needs to have in memory to successfully learn the new information. Three types of knowledge that seem to have an influence on the acquisition of information are background (i.e., domain), associative (i.e., sub-domain), and prerequisite. Background knowledge represents that level of specification of a domain as given in the Analysis Phase. Also to be considered is the relationship to other domains. For example, to fully understand the novel, Gone With the Wind, would require a background knowledge of the American Southern States culture before, during, and after the war between the states. The second type of entry knowledge is associative knowledge, which represents concepts and rules within the domain but within another context. For example, within the domain of structured programming languages are several languages. If a student was to learn within this domain the language of PASCAL, but had already learned BASIC, this would influence acquisition as contrasted with a student without BASIC. The third type of entry knowledge is the most common form, prerequisite knowledge. This knowledge is represented within memory at its most concrete level and is directly related to the information to be learned. Cognitive theory implies that for knowledge to be effectively retrieved, it must be encoded with the schematic connections.

#### Define Organization of Information

Once the information has been analyzed, the next authoring activity is to organize the information into an appropriate sequence for presentation. The activity at the most abstract level is organization into courses. This mapping is done in reference to program specifications from the Analysis Phase. The organization sequences the information from the course level into lessons and finally into modules. The purpose of the organizational plan is to be able to trace the specific information within a module back to the most abstract level of the domain. These traces would help clarify the entry knowledge for any given module.

#### Specify Learning System

All of the preceding activities establish the objectives and organization of the information to be learned within a given domain of information. As stated throughout the above narrative, the complexity of the procedures could be reduced and even in

many cases eliminated with an advanced instructional design advisor, allowing the author to apply the powerful techniques coming from cognitive science and instructional technology without the necessity of learning them. Within this component the specifications of the learning system are established, and could be likewise aided by an AIDA system. The primary activities include selecting the appropriate instructional strategies and management system.

The conventional ISD approach to determining an instructional strategy is to select a method of instruction independent of the information to be learned and the learning objectives. However, given the cognitive psychology paradigm of the knowledge base as more than a storage device, instructional strategies should provide methods that correspond to all forms of knowledge acquisition and employment.

For purposes of presenting the updated ISD model, I will continue to use a modification of Gagne's conditions of learning (Figure 1) and I will further identify instructional prescriptions that have direct relationships to specific learning objectives. These prescriptions are composed of instructional variables and conditions that have rich empirical-bases of support (for a review of the empirical findings see Tennyson & Breuer, 1984; Tennyson & Cocchirella, 1986; Tennyson, Thurlow, & Breuer, 1988). That is, instead of prescribing a given strategy of instruction for all forms of learning, I have identified categories of prescriptions, each composed of strategies that can be integrated according to given instructional situations.

Figure 2

---

Memory System Components	Declarative Knowledge	Procedural Knowledge	Contextual Knowledge	Cognitive Complexity	Total Cognitive Complexity
Learning Objectives	Verbal Information	Intellectual Skills	Contextual Skills	Cognitive Strategies	Creative Processes
Instruc- tional Prescrip- tions	Expository Strategies	Practice Strategies	Problem Oriented Strategies	Complex- Dynamic Strategies	Self- Directed Experiences
Instruc- tional variables	Label Definition Best Example Expository	Interroga- tory examples Format of examples	Sub-domain simulation Context error analysis	Domain simulation, role playing Domain	

Figure 2 (continued)

examples	Strategy	error
Worked	informa-	analysis
examples	tion	
	Skill error	
	analysis	
	Attribute	
	isolation	
	Advisement	
	Learning	
	time	
	Embedded	
	refreshment/ remediation	

Figure 2. Instructional systems design model linking cognitive learning theory with instructional prescriptions.

The five instructional prescription categories are as follows:

Expository strategies. This category represents those instructional variables designed to provide an environment for learning of declarative knowledge. The basic instructional variables provide a context for the to-be-learned information. Within this category, the concept of advance organizers (Ausubel, 1968) is extended to include a meaningful context as well as a framework of a given domains schematic structure. This instructional variables, context, establishes not only the initial structure of the domain but, also, introduces both the "why" (or theoretical nature of the information) and the "when" (i.e., the criteria of the domains standards, values, and appropriateness).

Following the contextual introduction of a given domain, the expository instructional variables present the ideas, concepts, principles, rules, etc., in forms to extend existing knowledge and to aid the establishment of new knowledge. The variables listed in Figure 2 include the following:

-**Label.** Identifies the appropriate term for the information.

-**Best Example.** An example that clearly demonstrates the information.

-**Expository Examples.** Additional examples that elaborate the information.

**-Worked Examples.** Worked examples is an expository environment in which the information is presented to the student in statement form (e.g., a lecture or text material). The purpose is to help the student in understanding both the context of the information and the structure of information (i.e., organization). For example, to learn a mathematical operation, the student is presented the steps of the process in an expository problem while, concurrently, presenting explanations for each step. In this way, the student can clearly understand the procedures of the mathematical operation without developing possible misconceptions often occurring with discovery methods of instruction (Petkovich & Tennyson, in press).

**Practice strategies.** This category of instructional prescriptions contains a rich variety of variables and conditions which can be designed into numerous strategies to improve learning (see Figure 2). This category is labelled practice, because the objective is to learn how to use knowledge correctly (i.e., the emphasis is on acquisition of procedural knowledge). Therefore, it requires constant interaction between student learning (e.g., problem solving) and instructional system monitoring. Practice strategies should attempt to create an environment in which (a) the student learns to apply knowledge to unencountered situations while (b) the instructional system carefully monitors the student's performance so as to both prevent and correct possible misconceptions of procedural knowledge.

The basic instructional method in this strategy is the presentation of interrogatory (question) problems that have not been previously encountered (see Tennyson & Cocchiarella, 1986, for a complete review of variables in this category). Other variables include means for evaluation of learner responses (e.g., pattern recognition), advisement (or coaching), elaboration of basic information (e.g., text density, Morrison et al., 1988), organization of information, number of problems, use of expository information, error analysis, and lastly, refreshment and remediation of prerequisite knowledge.

In schooling environments, peer tutoring has been shown to improve learning when tutors are trained with the above variables and are matched intellectually with the tutee. More recently, computer-based tutorial systems have employed advanced rule-based methods of programming to develop machine-intelligent applications of the above variables. For example, the MAIS system has successfully employed more than one of the above variables in an intelligent computer-assisted instructional system (Tennyson & Park, 1987).

**Problem-oriented strategies.** In the curricular planning phase of the updated ISD model (Figure 1), I propose that 25% of the instructional time be allocated to the acquisition of

contextual knowledge. A proposed instructional strategy for this category uses problem-oriented simulation techniques. The purpose of simulations is to improve the organization and accessibility of information within a knowledge base by presenting problems that require the student to search through their memory to locate and retrieve the appropriate knowledge to propose a solution. Within this context, the simulation is a problem rather than an expository demonstration of some situation or phenomenon.

In most discussions of knowledge base organizations, the specification of the accessibility process is elusive. However, in the field of artificial intelligence, the accessibility process is the most important function of an intelligent system. Within expert systems, contextual knowledge is represented in the form of the search rules (i.e., selection criteria). These rules are often in the form of production rules (e.g., IF THEN statements) or higher-order, meta rules. More advanced AI systems use fuzzy logic rules or conditional probability heuristics to account for problem situations requiring inferences that are more than mere dichotomous outcomes.

However, human memory systems, unlike computer-based AI systems, can self-generate the contextual knowledge of the knowledge base. The instructional key to improving this human cognitive process is the opportunity for the learner to participate in solving domain-specific problems that have a meaningful context (Ross, 1983; Ross, McCormick, & Krisak, 1986).

Problem-oriented simulations present domain specific problem situations to improve the organization and accessibility of information within the knowledge base. Basically, the strategy focuses on the students trying to employ their declarative and procedural knowledge in solving domain-specific problems. Problem-oriented simulations present task situations that require the student to (a) analyze the problem, (b) work out a conceptualization of the problem, (c) define specific goals for coping with the problem, and (d) propose a solution or decision. Unlike problems in the practice strategies that focus on acquiring procedural knowledge, problem-oriented simulations present tasks that require employment of the domain's procedural knowledge. Thus, the student is in a problem solving situation that requires establishing connections and associations among the facts, concepts, rules, and principles of specific domains of information.

To help students acquire a richer schematic network for their knowledge base, cooperative learning group techniques can become an integral condition of the problem-oriented simulation strategies. Within groups, students present and advocate their respective solutions to problems posed by the simulation. Research findings indicate that socialization is an important

condition in the improvement of contextual knowledge acquisition (e.g., Wagner & Sternberg, 1984). That is, the process of advocacy and controversy within the group provides an environment for students to both elaborate and extend their contextual knowledge. In other words, problem-oriented simulations add practical experience to the knowledge base not usually acquired by students until they are placed in a "real world" environment.

Complex-dynamic strategies. Instructional methods for developing thinking processes are often employed independent of given domains of information. For example, Feuerstein et al. (1980) present an elaborate training program to teach thinking skills by having students practice problem solving methods with nonsense tasks. The assumption is that after learning a set of generic, domain-independent problem solving skills, these skills can be transferred to domain specific situations. However, independently derived empirical findings of such training programs show little, if any transfer (Frederiksen, 1984). Part of the explanation for the failure of transfer, is that when subsequent domain-specific instruction is given, the focus is on acquisition of declarative and procedural knowledge rather than either acquisition of contextual knowledge or thinking processes development. Also, given the complexity of a knowledge base's organization, thinking skills do not provide sufficient means to cope with any but the simplest of problems (Gagne & Glaser, 1987).

In contrast to the many proposed training systems for domain-independent thinking skills development, simulations that present domain-specific problem situations allow learners to develop their thinking processes while employing the domain knowledge stored in their own memory systems. Complex-dynamic simulations extend the format of the problem-oriented simulations by use of an iterative problem format that not only shows the consequences of decisions but also updates the situational conditions and proceeds to make the next iteration more complex. That is, the simulation is longitudinal (i.e., dynamic), allowing for increasing difficulty of the situation as well as providing additions, deletions, and changes in variables and conditions. In more sophisticated complex-dynamic simulations these alterations and changes are done according to individual differences.

The main features of complex-dynamic simulations are: (a) present the initial variables and conditions of the situation; (b) assess the learner's proposed solution; and (c) establish the next iteration of the variables and conditions based on the cumulative efforts of the learner.

Instructional variables and conditions of a complex-problem simulation are as follows:

To further enhance the development and improvement of higher-order thinking processes with complex-problem simulations, we propose the employment of cooperative learning methods. Research findings (e.g., Breuer, 1985, 1987) indicate that intra-group interactions in problem-solving situations contribute to cognitive complexity development, because the learners are confronted with the different interpretations of the given simulation conditions by the other group members. In this way, new integrations among existing concepts within and between schemata can be established, alternative integrations to a given situation can be detected, and criteria for judging their validity can be developed.

In summary, complex-dynamic strategies should be designed to provide a learning environment in which learners develop and improve higher-order thinking processes by engaging in situations that require the employment of their knowledge base in the service of problem solving.

Self-directed experiences. The creative process is a cognitive ability that seemingly can be improved by learners who engage in activities requiring novel and valuable outcomes. That is, the creative process can be improved by instructional methods that allow students the opportunity to create knowledge within the context of a given domain. Instructional programs that provide an environment for easy manipulation of new information increase the learning time available for such activities. An example of such an environment is LOGO (Papert, 1980), a computer-based software program within the domain of mathematics. LOGO is especially helpful for those students who currently have a good declarative and procedural knowledge base of mathematics and need to elaborate their organization and accessibility of that knowledge.

Other computer-based software programs provide environments for self-directed learning experiences that may improve the creative process within given domains. For example, word processing programs have been shown to improve writing skills because of the ease in correcting and adjusting text structure (Lawler, 1985; Zvacek, 1988). Computer-based simulations have also shown that the creative process can be improved when students can both continually see the outcomes of their decisions while understanding the predictability of their decisions (Rasch, 1988).

The creative process is a cognitive ability that apparently can be improved with use within a domain and computer-based software programs seem to provide the type of environment which can enhance instructional methods for such improvements (Collins & Stevens, 1983). Because of the time necessary for participating in creative activities, educators should provide sufficient learning time for such development (Rasch, 1988).



Computer software programs that are domain specific enhance the cost-effectiveness of instructional strategies aimed at the improvement of creativity.

The key instructional attribute for this category is an environment that allows students to experience the creative process at that given moment. Computer software programs that are domain specific and provide for self-directed learning seem to offer excellent instructional strategies for meeting goals of a curriculum that emphasizes higher-level thinking strategies. Although, we have focused on computer-based software in this instructional category, there are of course other possible instructional means for students improving their creative processes.

#### Specify method of management.

The second activity in specifying the learning system is defining the parameters of the management system for the instruction. Cognitive psychology offers theoretical explanations that favor student responsibility in managing their learning and instructional technology offers management systems to provide student initiative. (Note. This area needs further elaboration).

#### Specify Message Design

Instructional technology provides an increasingly rich set of variables to enhance the presentation of information. The purpose of this activity is to improve the presentation to better represent the information to be learned. Thus, this component of the updated ISD model brings together the type of interaction proposed by Clark (1983). That is, the message design is more than a means to delivery instruction. For example, information that has a spatial quality as an integral critical attribute can be presented with an animated graphic to make a more complete representation of the information.

The task of an author here is to specify the design of the presentation in reference to the information to be learned. This is an area that AIDA may be able to aid an author by clarifying the display nature of the information. The author needs to match the attributes of the information with the available display elements and, if possible, the management system.

#### Specify Human Factors

Most of the ISD updates thus far have come primarily from both cognitive psychology and computer science, however, this component on human factors comes directly from educational technology. The human-machine interface is, of course, a concern for any field that has had any impact from modern technology.

The concern here is for identification of variables that will enhance learner interface with technology-based instruction. Although this is a relatively new field of study in educational technology, there is already a large body of literature on human factors. Much of the information is case study data coming from a raw-empiricism approach to CAI design, but there is sufficient experimental data to show major updates this area. Factors which an author needs to consider are such things as menu options, function key prompts, special helps, glossaries, and many other variables that may affect how learners interact with computers.

#### Specify Learner Evaluation System

The field of human testing and evaluation has gone through major changes in the past two decades, with current focus on learner assessment during learning and instruction. Examples are seen in ICAI programs and adaptive instructional systems that provide the means for on-task learning evaluation. The purpose of on-task assessment is to diagnose learning progress so as to adapt the instructional prescription to individual learner needs. Assessment methods range from a philosophy of preventive instruction (e.g., the MAIS system, Tennyson & Park, 1987) to reactive instruction (e.g., BUGGY, Burton & Brown, 1982).

Along with on-task assessment methods, an author needs to determine overall performance to determine the end of instruction evaluation. Adaptive testing systems are by their nature computer-based, but other forms of testing use the computer as a tool of computation only. In recent years there has been a focus in psychological testing on the effect of computers on assessment when compared to other traditional forms. That is, what does the computer bring to the testing situation that was not there before? The type of testing and evaluation will depend of the specifications set up in the Analysis Phase.

#### Specify Formative Evaluation System

In general, the purpose of formative evaluation is to obtain data necessary for making revisions and refinements of the instructional program during the Development Phase. Refinement refers to adjustments within single elements of the instructional design and/or development processes that do not affect the other elements; while revisions, on the other hand, refer to alternations in one element such it produces changes in one or more of the other elements. Data used for refinements and revisions are derived concurrently with each activity of the ISD process. Formative evaluation includes such activities as review of the information analysis by subject matter experts, validation of the test and instructional presentations, tryouts of the prototype instructional materials, and finally a tryout of the instruction in a simulated learning environment. Updates to the ISD model in this area come more from the field of program

evaluation then either cognitive science or instructional technology.

#### Review/Select Existing Materials

In the Analysis Phase a review of possible curricular and instructional materials is made to help decide on whether to develop new materials or existing materials. In this component a search is done to see if there are any materials available to assist in the development process. This could range from direct instructional materials to aids in helping in the development of materials (e.g., an authoring system). Efficiency of this activity could be improved by an AIDA.

#### Prepare Design Document

An important element of efficient instructional design is formulating a plan for administering the development process. The tasks to be accomplished to actualize the various instructional design components into a prototype of the learning program should be defined in a design document. Each design component dictates certain development decisions. For example, to operationalize the management strategy, each segment of the instruction should be specified as to level of system intelligence and learner control. This design document becomes the blueprint for the instructor and could be standardized in an AIDA.

#### Development Phase

During the development phase (Table 3), all instructional materials are produced as specified in the design document. The development of individual courseware components is accomplished in accordance with the design and development strategy specified during earlier phases. The result of the development phase is complete learning program which is ready for presentation.

Table 3

#### Authoring Activities in the Design Phase

##### Design Phase Steps

Specify Learning Objectives

##### Authoring Activities

State objectives for learning program, specifying: Desired conditions of learning (e.g., verbal information, intellectual skills, cognitive strategies, motor skills, attitudes)

Table 3 (continued)

Authoring Activities in the Design Phase

Analyze information structure	Determine schematic structure from knowledge base (referenced to conditions of learning) Determine schematic structure from semantic structure for content attribute characteristics
Define entry knowledge	Identify and determine learner entry knowledge and behaviors Determine learner (student) model: background knowledge, associative knowledge, prerequisite knowledge, prior knowledge
Define Organization and sequence of information	Determine sequence of information through: a) course, b) module, c) lesson
Specify learning system	State meta-instructional strategy
Specify meta-instructional strategies	Specify use of meta-instructional strategy variables: drill variables, placement of items, display time, label, definition, context, best examples, expository examples, interrogatory examples strategy operation, attribute elaboration
Specify meta-instructional strategies	
Specify mode of interaction	State level of system interaction: program initiative, mixed initiative
Specify screen management	Determine screen layout, postioning, sizing, etc.

Table 3 (continued)

Authoring Activities in the Design Phase

Specify presentation modes	Select input/output modes: Keyboard, positional, speech
Specify computer-based enhancements	Select computer-based enhancements: Worked examples, display time, format of examples, amount of information, sequence, embedded refreshment, and remediation
Specify methods of management	Design methods of management per selected level of intelligence: Flowchart, algorithmic, heuristic
Specify message design	Select display characteristics (e.g., graphics, text, color); Design screen layout
Specify human factors	Design: Menus, function key prompts, special helps, glossaries; Identify hardware configurations
Specify Learner Evaluation System	Determine on-task learning assessment and level of diagnosis (e.g., preventive, overlay, reactive, advisement, coaching) Determine use to be made of pretests, progress checks, and posttests; Determine how assessments are to be administered (i.e. by computer or paper)
Specify formative evaluation system	Outline strategy for validating learning learning materials

Table 3 (continued)

Authoring Activities in the Design Phase

Review/select existing materials	Select portions of existing materials appropriate for inclusion
Prepare document design	Document all design decisions to guide development of prototype learning materials

Prepare Content Narratives

A critical initial step in the development phase is the acquisition and documentation of all subject matter content required to achieve the stated objectives. Subject matter experts may aid the instructor (i.e., author) in the organization and preparation of the content. This task resembles information retrieval techniques.

Preparing Learning Activity Designs

After the required content is assembled, the content narratives are then structured by the author into the appropriate learning activity designs. Each learning activity design with all relevant content is then reviewed by an expert author (or even AIDA) to assure consistency with the design and by one or more subject matter experts to assure content accuracy and completeness.

Develop Learning Activities

The development of learning activities involves the structuring and writing of the content so that it will communicate effectively with the learner. The content of the first learning activity must be written and structured so as to employ the strengths of the medium and to maintain a sensitivity to the target audience characteristics and needs. Again, research in instruction technology offers development enhancements here.

Develop Assessment Instrument

The means of assessment and evaluation are developed in accordance with the intent of the learning objectives. For example, additional problem-oriented simulation items would measure contextual knowledge, while more conventional test items would measure declarative and procedural. The testing work

employing Bayesian methods appears to be offer advancements to this component of the updated ISD model.

### Reviews

An important concept adopted from computer science in the ISD process, is the importance of review and documentation. At this point in the development process, all instructional materials are in draft form. Proposed are two principal reviews of the materials. First, the subject matter experts review the materials to determine the technical accuracy and completeness of the materials. The SMEs also provide the feedback to the author so that necessary corrections may be made. Second, the author reviews the materials in order to determine whether they meet the requirements of the analysis and design phases. An AIDA system could provide this function.

### Editing of Learning Program

This activity is taken from the experience of the publishing community more directly than cognitive science or instructional technology. An editor should review all courseware materials for grammar, style, and consistency; make the necessary adjustments or corrections; and coordinates those changes with the author. Applications of computer-based systems to improve writing skills are only now being studied, but the initial findings show improvements (Zvacek, 1988).

### Formative Evaluation

The purpose of the formative evaluation is much like that of a pilot study in research, to make sure everything works before actually conducting the experiment. During this activity, the following tasks are performed:

- Conduct one-on-one tryout of draft materials
- Revise on the basis of one-on-one results
- Conduct small group pilot test(s)
- Revise on the basis of pilot results
- Simulation tryout with intended audience
- Revise and refine as needed

### Implementation Phase

During the implementation phase (Table 4), the instruction becomes part of the Air Force technical training school. The curriculum and instruction are used with the target population by the author. When the course is set up, any specific services required to deliver, maintain or support it are established. While the course is being used with its intended target population, data should be collected on student performance and attitudes. Information may also be recorded about the students' job performance after they complete the course. This practice

reflects the degree to which the original need/problem was solved.

Table 4

Authoring Activities in the Development Phase

<u>Development Phase Steps</u>	<u>Authoring Activities</u>
Prepare content narratives	Acquire and document subject matter content (i.e. knowledge base and schematic structure)
Prepare learning activity designs	Review learning designs and associated content for adherence to design and for accuracy and completeness
Develop learning activities	Employ strengths of medium; Implement instructional strategies
Develop assessment instrument designs	Develop items appropriate for each objective and learning activity; Develop items consistent with designed assessment system
Reviews	Subject matter experts review material for accuracy and completeness; Designers review material to determine whether it meets requirements established in analysis and development phases
Editing of learning program	Establish format and composition requirements; Review all materials for grammar, style, and consistency



Table 4 (continued)

Authoring Activities in the Development Phase

Formative Evaluation

Conduct one-on-one tryout of prototype materials; Revise on the basis of one-on-one result; Conduct simulation tryout; Refine on the basis of simulation test; Edit and produce; Perform technical and mechanical review

Documentation

Summative Evaluation

The evaluation in this activity (Table 5) is of a summative nature. It is intended to measure the effectiveness of the curricular and/or instructional problem identified in the analysis phase. Data gathered during field use are analyzed and summarized to comment on the quality of the instruction, especially in terms of improvements in learning. Cost-effectiveness can be determined to evaluate both the given situation the general approach of the ISD process.

Table 5

Authoring Activities in the Implementation Phase

Implementation Phase

Authoring Activities

Reproduce materials  
Establish/modify support services;  
Distribute materials;  
Deliver instruction;  
Collect data on learner performance and attitude

Maintenance Phase

This phase (Table 6) is usually not considered in the conventional ISD model, but it can influence the longitudinal quality of instruction. The purpose of the maintenance phase is

to maintain the instruction at or near the level of effectiveness as when first implemented. Updates to the ISD model are derived from the field of program evaluation and instructional technology. The guidelines presented below could be included in the AIDA as both an initial activity (i.e., preceding the Analysis Phase) and as the means of continuing an interaction with AIDA as instructors seek to improve their current instructional programs and materials.

First, are the instructional materials still worth using in the learning environment? This question refers to the concept of cost-benefits. In other words, do the benefits derived from the product justify the costs? In the case of instructional materials (e.g., video), are they achieving the goals and objectives of the instruction? Benefits include such factors as high learning levels, positive learner attitudes and an efficient management system. The Air Force technical training, probably the most important source of data to be analyzed would be the performances of the learners after they have finished the instruction. This can be immediate performance, such as performance at the next level of instruction, or performance after transferring to the job. Collection of this type of data is useful in updating the goals and objectives of not only the instruction but the entire curriculum.

Second, updating the information is an important consideration in keeping instructional products and materials current. This factor is one of the major concerns of the Air Force technical training schools, and one of the main purposes for proposing AIDA. Within the context of the AIDA, a procedure could be set up by which the instructor would review the information of a course in light of changes in the domain and to update the instruction accordingly. The assumption within the conventional ISD model that content in any domain will remain constant for five years (usually the standard time for shelf life of mediated materials) without updating is incorrect. AIDA should assume that periodic changes to instructional content need to be made.

Third, learner attitudes toward the instruction and materials should be measured along with performance measures. Learner attitudes do fluctuate; they need to be reassessed after instructional materials have been used over a period of time. Factors which usually affect student attitudes are out-of-date visuals, poor condition of photographic displays (e.g., film and slides), missing learning materials or any other components of the system which do not meet the technical standards of the original product or materials. Student attitudes of this kind are obtained not by questionnaires alone, but by one-to-one interviews and small group discussions; where possible, anonymous inputs solicited by the instructors are helpful.

Fourth, changes in individual characteristics of the learner need to be evaluated. Certainly the Air Force technical training schools have had to reassess the goals and basic educational needs of the students. Societal policies change periodically, requiring that instructional goals and objectives change accordingly. Likewise, learner goals fluctuate, necessitating adjustments in learning environments and possibly changes in the instruction. For a variety of reasons, learner prerequisites change over time, requiring possible changes in the instructional system.

Fifth, if some form of media is involved in the instructional delivery system (another major goal of AIDA), that must be evaluated and maintained as well. New media sources should be incorporated when possible. For example, computerizing standard tests (much like has been done in clinical psychology over the past few years) could provide additional years of usage to instructional materials. Integrating media into existing instructional systems could improve the efficiency of the learning. Modification of the instructional delivery system is often an inexpensive method of updating instruction.

Maintenance evaluation makes it possible to prolong the life of developed instruction while maintaining the original effectiveness and efficiency. To make significant gains in developing new instruction requires that a method of maintaining current materials be employed. The proposed updated ISD model views instructional development within a broader context of both new development and maintaining previously developed instruction.

Table 6

#### Authoring Activities in the Maintenance Phase

##### Maintenance Phase

##### Authoring Activities

Determine whether to  
make major revision  
(go to analysis phase)  
or minor revision  
(Stay in Maintenance);  
Perform maintenance on  
learning activities  
and test items

## Summary

A wide discrepancy exists between the learning theory base underlying ISD and that underlying recent advances in instructional psychology. ISD models have proliferated for the most part in response to discoveries made by instructional developers. The lack of a research-based rationale for many innovations in ISD makes it highly probable that the innovators will attribute instructional improvements to apparent causes rather than the underlying ones which are often quite complex.

The proposed update of ISD recognizes the complexity of the instructional design process and therefore the varying importance of research-based and development-based prescriptions for different aspects of instructional development. Thus the proposed update to the ISD process incorporates validated prescriptions from empirical research in the cognitive and instructional sciences, from multi-media technology developments, and from documented implementations of ISD.

Among the features of the cognitive update of ISD are explicit descriptions of the learning conditions in the instructional environment, coupled with statements of the expected relationships among the learning variables in the domain of concern. This provides an initial view of the structure of the domain knowledge base. Other critical information needs are specified as well: The learning problem scope, knowledge acquisition goals, delivery system specifications, organization and sequence of information, instructional strategies, and an assessment of available learning resources and facilities. In the development phase of the updated ISD tentative answers to the information needs are generated and subjected to formative evaluation. The development effort is guided by a design documents which summarizes all design decisions.

With the modifications made to the baseline ISD process the updated version will be able to address learning requirements which call for learners to acquire accurate mental models regardless of the domain in question.

## V. CONCLUSIONS (Muraida)

Gagne, Kintsch, and Tennyson offer three related but distinct approaches to instructional prescriptions from cognitively-oriented psychological research (See Vol. 1 for a review). Taken together their contributions offer the instructional designer directives which will apply to virtually all instructional settings, a synopsis of the applicability of major research findings to instruction, and an approach the application of research findings to large scale instructional development efforts.

Obviously research implications for every instructional contingency is an impossibility. Expecting basic researchers to produce highly specific prescriptions would divert them from the purpose of identifying generalized phenomena. It may well be in the province of the instructional technology community to test "proximal" hypotheses (van Mondfrans, et al, 1977) in the course of their instructional development activities. This refers to extrapolations of instructional design principles tested out in the context of an instructional development project. The aim of such work is to determine how robust those principles are in application. In subsequent volumes of this series many of the principles expounded here are elaborated in the context of visual presentation methods for instruction (Vol. 4, Friedman) and architectures for instructional design advisory systems (Vol. 5, Gagne, Tennyson; Vol. 6, Merrill). These are examples of the different approaches which might be taken to expand on the raw implications that come from basic research. The care with which these extrapolations are implemented and the degree to which they produce useful information may ultimately determine how useful the cognitive sciences will be for instructional design.

## References

- Anderson, J.R. (1987) Skill acquisition: Compilation of weak-method problem solutions. Psychological Review, 94 (2), 192-210.
- Anderson, J.R., Boyle, C.F., and Yost, G. (1985). The geometry tutor. In Proceedings of the International Joint Conference on Artificial Intelligence-85 (pp-1-7). Los Angeles: International Joint Conference on Artificial Intelligence.
- Andrews, D.H., and Goodsen, L.A. (1980). A comparative analysis of models of instructional design. Journal of Instructional Development, 3: 2-16.
- Ausubel, D.P. (1968). Educational Psychology: A cognitive view. New York: Holt, Rinehart, and Winston.
- Bereiter, C. and Scardamalia, M. (1989) Intentional learning as a goal of instruction. In L.B. Resnick (Ed). Knowing, learning, and instruction: Essays in honor of Robert Glaser. Hillsdale, NJ: Erlbaum.
- Bloom, B. S. (1956). Taxonomy of educational objectives. Handbook I: Cognitive Domain. New York: McKay
- Breuer, K. (1985). Computer simulations and cognitive development. In K.A. Duncan and D. Harris (Eds.), Proceedings of the world conference on computers in education 1985 WCCE/85 Amsterdam, The Netherlands: North Holland.
- Brown, A.L. and Palincsar, A.S. (1989). Guided, cooperative learning and individual knowledge acquisition. In L.B. Resnick (1989), (Ed). Knowing, learning, and instruction: Essays in honor of Robert Glaser. Hillsdale, NJ: Erlbaum.
- Burton, R.R., and Brown, J.S. (1982). An investigation of computer coaching for informal learning activities. In D. Sleeman and J.S. Brown (Eds.) Intelligent Tutoring Systems. New York: Academic Press.
- Clark, R.E. (1983) Reconsidering research on learning from media. Review of Educational Research, 53, 445-460.
- Collins, A., and Stevens, A.L. (1983). A cognitive theory of interactive teaching. In C.M. Reigeluth (Ed.), Instructional Design Theories and Models. Hillsdale, NJ: Erlbaum.

- Collins, A., Brown, J.S., and Newman, S.E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L.B. Resnick (1989), (Ed) Knowing, learning, and instruction: Essays in honor of Robert Glaser.
- Crowder, N.A. (1959). Automatic tutoring by means of intrinsic programming. In E.H. Galanter (Ed.) Automatic Teaching: The State of the Art, New York: John Wiley.
- van Dijk, T.A., and Kintsch, W. (1983). Strategies of discourse comprehension. New York: Academic Press.
- Feuerstein, R., Rand, Y., Hoffman, M.B., and Miller, B., (1980). Instrumental Enrichment, Baltimore: University Park Press.
- Frederiksen, N. (1984). Implications of cognitive theory for instruction in problem solving. Review of Educational Research 54, 363-407.
- Gagne, R. M. (1970). The conditions of learning .(2nd ed.) New York: Holt, Rinehart, and Winston.
- Gagne, R.M. (1985). The conditions of learning. (4th ed.). New York: Holt, Rinehart, and Winston.
- Gagne, R.M., and Glaser, R. (1987). Foundations in learning research. In R.M. Gagne (Ed.) Instructional Technology: Foundations. Hillsdale, NJ: Erlbaum.
- Glaser, R. (1965) Toward a behavioral science base for instructional design. In R. Glaser (Ed.) Teaching Machines and programmed learning. Washington, D.C.: National Education Association.
- Glaser, R. (1989). Expertise and learning: How do we think about instructional processes now that we have discovered knowledge structures? In D. Klahr and K. Kotovsky (Eds.), Complex information processing: The impact of Herbert Simon. Hillsdale, NJ: Erlbaum.
- Glaser, R., and Bassock, M. (1989). Learning theory and the study of instruction. In M.R. Rosenweig and W. Porter (Eds.) Annual Review of Psychology. (Vol. 40, pp. 631-666). Palo Alto, CA: Annual Reviews Inc.
- Gropper, G.L. (1983). A behavioral approach to instructional prescription. In C.M. Reigeluth (Ed.) Instructional Design Theories and Models. Hillsdale, NJ: Erlbaum.
- Kintsch, W. (1989) A theory of discourse comprehension: Implications for a tutor of word algebra problems. Paper

presented at meetings of the European Association for Research in Learning and Instruction. Madrid.

- Lawler, R. (1985). Computer experience and cognitive development. New York: John Wiley.
- Mandler, J.M. (1979) Categorical and schematic organization in memory. In C.R. Puff (Ed.), Memory organization and structure. New York: Academic Press.
- Merrill, M.D. (1983). Component display theory. In C.M. Reigeluth (Ed.), Instructional Design Theories and Models. Hillsdale, NJ: Erlbaum.
- Merrill, M.D. (1986). Prescriptions for an authoring system. Journal of Computer-Based Instruction, 12(4), 90-96.
- Merrill, M.D., and Wood, N.D. (1975). An instructional strategy taxonomy: Theory and applications. Journal for Research in Mathematics Education, 6(4), 195-201.
- van Mondfrans, A.P., Black, H.B., Keysor, R.E., Olsen, J.B., Shelly, M.F., and Williams, D.D. (1977). Methods of inquiry in educational psychology. In D.J. Treffinger, J.K. Davis, and R.E. Ripple (Eds.) Handbook on Teaching Educational Psychology. New York: Academic Press.
- Morrison, G.R., Ross, S.M., O'Dell, J.K., Schultz, C.W., and Higginbotham-Wheat, N. (1988). Implications for the design of computer-based instruction screens. Computers in Human Behavior, 5, 167-174.
- Palincsar, A.S. and Brown, A.L. (1984). Reciprocal teaching of comprehension-fostering and monitoring activities. Cognition and Instruction, 1(2), 117-175.
- Papert, S. (1980). Mindstorms: children, computers, and powerful ideas. New York: Basic Books.
- Park, O., Perez, R.S., and Seidel, R.J. (1987). Intelligent CAI: Old wine in new bottles, or a new vintage? In G.P. Kearsley (Ed.), Artificial intelligence and instruction: Applications and methods, Reading, MA: Addison-Wesley.
- Perfetti, C.A. (1989). There are generalized abilities and one of them is reading. In L.B. Resnick (Ed.), Knowing, learning, and instruction: Essays in honor of Robert Glaser. Hillsdale, NJ: Erlbaum.
- Petkovich, M.D. and Tennyson, R.D. (1990). Teaching mathematics skills with worked examples: Effects of accompanying text and range of examples using computer-based instruction. Unpublished manuscript.



- Rasch, M. (1988). Computer-based instructional strategies to improve creativity. Computers in Human Behavior, 4, 23-28.
- Reigeluth, C.M. (1983) (Ed.) Instructional Design Theories and Models. Hillsdale, NJ:Erlbaum.
- Reigeluth, C.M. (1987). A prescriptive theory for the design of simulations. Paper presented at the Annual Meeting of the American Educational Research Association. Washington, DC.
- Reigeluth, C.M., Merrill, M.D., and Bunderson, C.V. (1978). The structure of subject matter content and its instructional design implications. Instructional Science, 7, 107-126.
- Resnick, L.B. (1989) Introduction. In L.B. Resnick (Ed.), Knowing, learning, and instruction: Essays in honor of Robert Glaser. Hillsdale, NJ:Erlbaum.
- Ross, S.M. (1983). Increasing the meaningfulness of quantitative material by adapting context to student background. Journal of Educational Psychology, 75, 519-529.
- Ross, S.M., McCormick, D., and Krisak, N. (1986) Adapting the thematic context of mathematical problems to student interests: Individualized versus group-based strategies. Journal of Educational Research, 79(4), 245-252.
- Salomon, G. (1983). The differential investment in mental effort in learning from different sources. Educational Psychologist, 18, 42-51.
- Salomon, G. (1985) Information Technologies: What you see is not (always) what you get. Educational Psychologist, 20, 207-216.
- Scardamalia, M. and Bereiter, C. (1985). Fostering the development of self-regulation in children's knowledge processing. In S.F. Chipman, J.W. Segal, and R. Glaser (Eds.), Thinking and learning skills: Research and Open Questions (Vol. 2). Hillsdale, NJ:Erlbaum.
- Scardamalia, M., Bereiter, C., McLean, R.S., Swallow, J., and Woodruff, E. (1989). Computer-supported intentional learning environments. Journal of Educational Computing Research, 5(1), 51-68.
- Scardamalia, M. Bereiter, C. and Steinbach, R. (1984). Teachability of reflective processes in written composition. Cognitive Science, 8, 173-190.
- Schneider, W. (1985) Training high performance skills: Fallacies and guidelines. Human Factors, 27(3), 285-300.

- Simon, H.A. (1980) Cognitive Science: The newest science of the artificial. Cognitive Science 4(1), 33-46.
- Skinner, B.F. (1954). The science of learning and the art of teaching. Harvard Educational Review, 24, 86-97.
- Skinner, B.F. (1968). The technology of teaching. New York: Appleton-Century-Crofts.
- Spector, J. Michael (1990) Designing and Developing an Advanced Instructional Design Advisor Technical Paper, Air Force Human Resources Laboratory, AFHRL-TP-90-52 July.
- Tennyson, R.D. (1977) Instructional systems: Development, evaluation, and management of learning environments. In D.J. Treffinger, J.K. Davis, and R.E. Ripple (Eds.) Handbook on Teaching Educational Psychology. New York: Academic Press.
- Tennyson, R.D. (1978) Evaluation technology in instructional development Journal of Instructional Development , 2(1), 19-26.
- Tennyson, R.D. (1981). Interactive effects of cognitive learning theory with computer attributes in the design of computer-assisted instruction. Journal of Educational Technology Systems. 10, 175-186.
- Tennyson, R.D., and Breuer, K. (1984). Cognitive-based design guidelines for using video and computer technology in course development. In O. Zuber-Skerritt (Ed.) Video in Higher Education. London: Kogan.
- Tennyson, R.D. and Cocchiarella, M.J. (1986). An empirically based instructional design theory for concept teaching. Review of Educational Research. 36, 40-71.
- Tennyson, R.D. and Rasch, M. (1988) Linking cognitive theory to instructional prescriptions. Instructional Science, 17, 369-385.
- Tennyson, R.D., and Park, O. (1987) Artificial intelligence and computer-assisted learning. In R.M. Gagne (Ed.) Instructional Technology: Foundations, Hillsdale, NJ: Erlbaum.
- Tennyson, R.D., Thurlow, R., and Breuer, K. (1988). Problem oriented simulations to develop and improve higher thinking strategies. Computers in Human Behavior, 3, 151-165.

Thorndike, E.L. (1914) The psychology of learning: Educational Psychology. New York: Teachers College Press. Vol. 2

Wagner, R.K., and Sternberg, R.J. (1984) Alternative conceptions of intelligence and their implications for education. Review of Educational Research, 54(2), 179-223.

Zvacek, S.M. (1988). Word processing and the teaching of writing. Computers in Human Behavior, 4, 29-36.